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COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

REPORT ON THE SEVENTH UNITED NATIONS INTERNATIONAL TRAINING COURSE ON REMOTE SENSING EDUCATION FOR EDUCATORS

(Stockholm and Kiruna, Sweden, 5 May to 13 June 1997)

CONTENTS

	Paragraphs	*Page*
INTRODUCTION	1-5	1
A. Background and objectives	1-2	1
B. Organization and programme	3-5	2
I. SUMMARY OF THE CONTENTS OF THE COURSE	6-14	2
II. COURSE EVALUATION	15-16	3
III. PROPOSED FOLLOW-UP ACTION	17	4

INTRODUCTION

A. Background and objectives

1. The Seventh United Nations International Training Course on Remote Sensing Education for Educators, held at Stockholm and Kiruna, Sweden, from 5 May to 13 June 1997, was organized by the United Nations Programme on Space Application in cooperation with the Government of Sweden. The course was conducted specifically for the benefit of educators from developing countries with the objective of enabling them to introduce remote sensing courses in their respective academic institutions. It was co-sponsored by the Swedish International Development Agency (SIDA) on behalf of the Government of Sweden and was hosted by the

Department of Physical Geography of Stockholm University, at Stockholm, and the Swedish Space Corporation (SSC Satellitbild).

2. The present report describes the organization of the training course, its technical contents, the results of the course evaluation and the proposed follow-up actions. It has been prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee.

B. Organization and programme

3. Application forms and information brochures on the training course were sent out in November 1996 by the Office for Outer Space Affairs of the United Nations to offices of the United Nations Development Programme for transmission to the relevant national authorities in 48 developing countries. The same material was also distributed simultaneously to relevant Swedish embassies and to previous course participants for circulation in their academic institutions. Eighty-seven completed applications were subsequently received and jointly processed by the United Nations Office for Outer Space Affairs and Stockholm University. The selection of participants was completed by the end of February 1997, approximately two months before the start of the course.

4. Twenty-seven candidates, including nine women, were selected as participants. The participants were nationals of the following 20 countries: Bolivia, Brazil, Cambodia, Costa Rica, Haiti, Kenya, Lao People's Democratic Republic, Lesotho, Mozambique, Myanmar, Nepal, Nicaragua, Pakistan, Paraguay, Sri Lanka, Thailand, Uganda, United Republic of Tanzania, Zambia and Zimbabwe. Funds for the international travel of 13 participants were provided from the fellowship budget of the United Nations Programme on Space Applications. All other support, including international travel of the remaining 14 participants, room and board, course materials, and inland transport for all 27 participants, was provided by the Government of Sweden.

5. Course instructors and speakers came from several institutions, including the Office for Outer Space Affairs, European Space Agency (ESA), SIDA, Stockholm University, Royal College of Technology, Uppsala University, Swedish Royal Institute of Technology, Swedish National Space Board, Swedish Society for Nature Conservation and SSC Satellitbild.

I. SUMMARY OF THE CONTENTS OF THE COURSE

6. The technical contents of the course were determined by the Department of Physical Geography of Stockholm University, with input from the Office for Outer Space Affairs. The course was modular in format and consisted of a series of lectures and office and field exercises. A more detailed summary of the contents of the course can be found in the report on the fifth course in the series (A/AC.105/617).

7. The first technical module of the course lasted three days and dealt with the fundamental principles of remote sensing. The principal topics covered were the following: electromagnetic radiation, the reflective properties of various types of materials on the surface of the Earth, and elementary optics; electronic imaging; georeferencing of objects in the field, on maps and on satellite imagery; and Earth resources and environmental satellites.

8. Five days were subsequently devoted to image interpretation and presentations on the following subjects: remote sensing for land-use planning and environmental monitoring; remote sensing for geological studies; introduction to visual interpretation and in-service training in developing countries.

9. To reinforce understanding of the principles of image interpretation, participants were divided on a regional basis into groups, each of which studied a case history where visual interpretation of satellite images played a key role. The case histories were: land and water development in Ethiopia; land-use mapping in the United Republic of Tanzania; forestry in Ecuador; geological applications in Central America; environmental impact assessment of the closure of a river arm in Bangladesh; and environmental impact assessment of hydropower development in the Lao People's Democratic Republic. Participants made presentations on the state of development of remote sensing in their respective countries.

10. An additional series of lectures dealt with digital image analysis and geographic information systems (GIS). This section lasted six days and covered the following subjects: digital analysis (theory); computer image enhancement (theory); GIS theory; and digital image processing techniques, including computer-aided analysis, GIS applications, CD-ROM, data capture, compass techniques and global positioning systems.

11. The participants were also introduced, over a period of three days, to the principles of radar image formation and the use of such images in various development and research applications. In addition, they were introduced to the use of appropriate procedures for the field verification of interpretations of remotely sensed data using satellite images of the Skinnskatteberg area of southern Sweden.

12. The succeeding part of the course was held at Kiruna, at the facilities of SSC Satellitbild. Four days were reserved for visual interpretation exercises and the presentation of results. Wherever possible, the exercises were carried out on images selected by the participants of regions of their countries with which they were familiar. Lectures were presented on the following subjects: archiving, catalogue updating and standard production of images; image processing, value-added production, radiometric and geometric corrections, and production of digital elevation models and orthoimages; computerized cartography; standard and higher level processed imagery; and future Earth-resources satellites.

13. During this part of the course, the representative of the United Nations made a presentation entitled "Tele-education for development: a priority theme of the COPINE project". While at Kiruna, the participants had the opportunity to visit a number of sites of interest, including the ESA/Salmijarvi and Esrange satellite receiving stations, and the Kirunavaara underground mine. Lectures were supplemented by tours of the production facilities of SSC Satellitbild.

14. The final part of the course concerned the development of remote sensing curricula, and was held over a period of one and one-half days at the Department of Physical Geography of Stockholm University. It was followed by a half-day session reserved for formal evaluation of the course.

II. COURSE EVALUATION

15. Participants made a formal presentation of the course evaluation to representatives from the Office for Outer Space Affairs, SIDA, the Department of Geography of Stockholm University and several selected course lecturers. Additional input was provided by all participants in discussions following the formal presentation.

16. The participants' opinions extracted from 26 completed questionnaires can be summarized as follows: (a) 73 per cent thought the course was right in length; (b) 38 per cent found the schedule too heavy; (c) 65 per cent found that the theoretical training corresponded to their professional needs to a large or very large extent whereas 50 per cent found that to be the case for the practical training; (d) 88 per cent found the overall level of the programme to be adequate from their personal professional point of view; (e) 77 per cent found that there were subjects not adequately covered in the programme; (f) 81 per cent found the methods of instruction to be

good or very good; and (g) 77 per cent thought that they would have an opportunity to apply the newly acquired knowledge and experience in their current employment to a great or very great extent.

III. PROPOSED FOLLOW-UP ACTIONS

17. A proposal to organize a workshop in 1998 focusing on a technical evaluation of the present course and determining its future direction was developed jointly by Stockholm University and the Office for Outer Space Affairs. The experiences of past participants subsequent to their attending the course would be a major input to the final outcome of the workshop. The proposal would be submitted in the last quarter of 1997 to SIDA for funding consideration.

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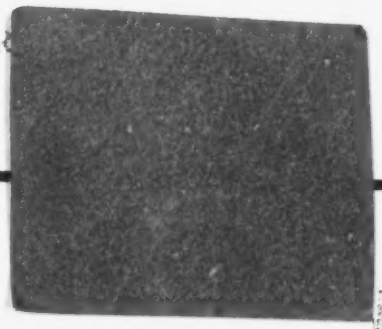

IMPLEMENTATION OF THE RECOMMENDATIONS OF THE SECOND UNITED NATIONS CONFERENCE ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE

International cooperation in the peaceful uses of outer space: activities of Member States

Note by the Secretariat

CONTENTS

	Paragraphs	*Page*
INTRODUCTION	1-7	2
REPLIES RECEIVED FROM MEMBER STATES		3
Belgium		3
Brunei Darussalam		5
Canada		5
Chile		8
Cuba		9
India		10
Indonesia		12
Italy		19
Japan		25
Malaysia		29
Sweden		30
Switzerland		36
United Kingdom of Great Britain and Northern Ireland		39
United States of America		39

INTRODUCTION

1. In the report on the work of its eleventh session (A/AC.105/672, annex II), the Working Group of the Whole to Evaluate the Implementation of the Recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space made recommendations concerning the preparation of reports and studies by the Secretariat and the compilation of information from Member States.

2. In paragraph 8 of its report, the Working Group recommended that, in the light of the continued development and evolution of space activities, the Committee on the Peaceful Uses of Outer Space should request all States, particularly those with major space or space-related capabilities, to continue to inform the Secretary-General annually, as appropriate, about those space activities that were or could be the subject of greater international cooperation, with particular emphasis on the needs of the developing countries.

3. The report of the Working Group was adopted by the Scientific and Technical Subcommittee at its thirty-fourth session (A/AC.105/672, para. 22), and the recommendations of the Working Group were endorsed by the Committee on the Peaceful Uses of Outer Space at its fortieth session.[1]

4. Subsequently, in a note verbale dated 7 August 1997 from the Secretary-General to all permanent representatives to the United Nations, the Secretary-General requested all Governments to communicate to the Secretariat by 30 September 1997 the information requested in the above-mentioned recommendations.

5. In addition, the Secretary-General, in his note verbale, drew the attention of Governments to the recommendation, endorsed by the Committee, that the Secretariat should invite Member States to submit annual reports on their space activities. Besides information on national and international space programmes, the reports could include information in response to requests from the Working Group of the Whole, on spin-off benefits of space activities and other topics as requested by the Committee and its subsidiary bodies.[2]

6. In accordance with the recommendation of the Committee, the Secretary-General, in his note verbale, suggested that Governments could submit in a single report information on topics requested by the Committee and its subsidiary bodies, in particular information on the following topics:

(a) Those space activities that were or could be the subject of greater international cooperation, with particular emphasis on the needs of the developing countries;

(b) Spin-off benefits of space activities;

(c) National and international research concerning the safety of nuclear-powered satellites;

(d) Studies conducted on the problem of the collision of nuclear power sources with space debris;

(e) National research on space debris.

7. The present document was prepared by the Secretariat on the basis of information received from Member States by 31 October 1997 on the topics listed above in paragraph 6, subparagraphs (a) and (b). Information received subsequent to that date will be included in addenda to the present document. Information received regarding the topics listed in paragraph 6, subparagraphs (c) to (e), is presented in a separate document (A/AC.105/680).

Notes

[1] *Official Records of the General Assembly, Fifty-second Session, Supplement No. 20* (A/52/20), para. 29.

[2] Ibid., para.163.

REPLIES RECEIVED FROM MEMBER STATES*

BELGIUM

[Original: French]

The year 1995 was a very important one for space activities. From 18 to 20 October, the Ministerial Space Conference was held, in Toulouse, with the task of deciding on the direction of European space policy between now and the beginning of the next century.

The chairmanship of this Ministerial Conference was entrusted to the Belgian Minister responsible for scientific policy. This serves to reinforce the not insignificant political position which has been assumed by Belgium in this major sector of European construction and which has been strengthened by both industrial and scientific capabilities.

The bulk of the activities of the SSTC space division during the past year thus centred on preparations for the Toulouse Conference, both at the Belgian level and at that of the European Space Agency.

The Ministerial Conference focused on a series of decisions that would meet the specific concerns of the member countries within the framework of a comprehensive and coordinated European strategy, while maintaining a balance between the objectives of European independence in space and international cooperation.

Specifically, the Toulouse decisions related to:

(a) Involvement in the International Space Station project, a major challenge in terms of global cooperation for scientific purposes with the other main space partners: the United States of America, Russian Federation, Japan and Canada. The European contribution has taken the form of the implementation of the "Man in Space" programme, comprising:

- A European laboratory, the Columbus Orbital Facility (COF), docked with the international space station;
- An Automated Transfer Vehicle (ATV), designed to carry freight and fuel to the space station and expand its orbit;
- Preparatory studies for a Crew Transport Vehicle (CTV); a decision regarding the transition to the development phase is to be taken at the next ministerial conference, due to be held in Brussels in the spring of 1998;
- Equipment for the COF laboratory; this forms a subject of a separate development programme, known as MFC (Microgravity Facilities for COF);

(b) Improvement of the technical and commercial capabilities of the Ariane-5 launcher, which is the chief means for acquiring independent European access to space. With a view to achieving this objective, the supplementary Ariane-5 programmes have been approved;

(c) Confirmation of the strategic options for the programmes to be implemented during the period 1996-2000 in fields such as:

- Observation of the Earth and its environment;

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*The replies have been reproduced in the form in which they were received.

- Natural phenomena;
- Telecommunications;
- The scientific programme;
- Microgravity;
- New space technologies;
- Mini-satellites.

At the Belgian level, an inter-cabinet group has formulated Belgium's priorities in these various programmes of the European Space Agency, and a mandate was given to the Minister for Scientific Policy, by the Council of Ministers, providing for a commitment over the period 1996-2000, as part of an ongoing overall multi-annual budget, of 6,000 million Belgian francs.

Under this mandate, Belgium made contributions in Toulouse:

- To the "Man in Space" programme at a rate of 3 per cent, i.e. a rate equivalent to its GNP rate, and to the MFC programme at a rate of 10 per cent. These rates are in keeping with Belgium's existing scientific and industrial capabilities;
- To the supplementary Ariane-5 programmes at rates ranging from 3 to 6 per cent according to the anticipated activities in these three programmes, with the aim of maintaining the high standard of the specific industrial capabilities established in Belgium since the 1970s and thus preserving their advantageous position in the industrial consortium marketing the launch vehicle.

Given that space is a major aspect of the new information society and an essential factor in the implementation of a sustainable development policy owing to the impact which it has on:

- Our knowledge of the Earth and its biosphere;
- Telecommunications;
- The scientific progress achievable by means of the satellites and infrastructures in orbit,

Belgium has also reinforced its position in the fields of observation of the Earth and its environment, use of space for scientific purposes, telecommunications, and technological research and development in these various fields.

Belgium accordingly announced in Toulouse its contribution rates for:

- Metop 3 per cent
- Data Users Programme 4 per cent
- EOPP Extension 3 per cent
- EMIR 2 4 per cent
- ARTES 64 million accounting units
- PRODEX 24 million accounting units
- GSTP2 and TDP3 53 million accounting units

With regard to bilateral cooperation with France on the SPOT Earth observation satellites, which dates from 1979, Belgium has decided to continue supporting this area through involvement in the development of the SPOT-5 satellites. To this end, the Council of Ministers which met on 31 March 1995 indicated its agreement to the allocation of 1,916 million Belgian francs from the SSTC space budget for SPOT-5, for the operation of the Vegetation Monitoring Instrument to be installed on the SPOT-4 satellite, and for a contribution to the second model of this instrument.

The development of the first vegetation model, which was decided upon in 1994, is proceeding according to schedule, and it has been possible to secure agreement from the partners (France, Sweden, Italy, European Commission) that the vegetation image processing centre (CTIV), which was in fact developed by Belgian industry, will be installed at VITO in Mol. This is the first time that Belgium has been assigned an active role in the use and marketing of data.

BRUNEI DARUSSALAM

[Original: English]

The Government of Brunei Darussalam reports that it does not have any outer-space-related programmes or activities.

CANADA

[Original: English]

1997 marked the 35th anniversary of the beginning of the Canadian Space Program. The country's first satellite, Alouette I, a communications satellite, was launched on 29 September 1962, making Canada only the third nation in the world to enter the space age. Canada has since gone on to become an international leader in satellite communications, space-based remote sensing, space robotics, and space-based scientific research. Today, as in 1962, Canadian activities in human space flight, Earth observation, satellite communications, space science, and space technology development ensure that Canada makes an important contribution to the global space knowledge base and that space is used to generate socio-economic benefits for Canadians and humanity in general.

Some of Canada's activities in space during 1997 are summarized below.

A. International Space Station

Work is continuing on the Mobile Servicing System (MSS), Canada's contribution to the International Space Station. The MSS is a sophisticated robotics system that will play an important role in the assembly, maintenance, and servicing of the Space Station, in which Canada is a partner with the United States of America, participating member States of the European Space Agency, Japan, and Russian Federation. The flight RMS, the robotic manipulator, is undergoing the final system-level integration and tests and will be delivered in early 1998 for planned launch in June 1999. The flight MBS, the mobile base, is being manufactured and assembled and will be delivered in late 1998 for planned launch in March 2000.

One of the most significant events of this past year has been Canada's decision to manufacture the Special Purpose Dexterous Manipulator (SPDM), scheduled for launch in January 2002. The SPDM will be a key component of the Mobile Servicing System and will be used with a new generation of "Canadarm" to assemble and maintain the International Space Station in orbit. Canadian Prime Minister Jean Chrétien made this announcement in Washington on 8 April 1997, during a White House press conference with President Bill Clinton of the United States of America. This announcement was a reaffirmation of Canada's commitment to being a full partner in the largest and most complex international science and technology project in history.

B. Earth observation

Canada's first Earth observation satellite, RADARSAT, is continuing to exceed expectations. Operated by the Canadian Space Agency (CSA), RADARSAT monitors the environment and supports natural resource management worldwide. Its data are received by the Canada Centre for Remote Sensing (CCRS) and are processed and distributed by RADARSAT International Inc. (RSI). Currently the system is generating approximately 2,000 scenes per month, a figure that will increase as network receiving stations come on line. To date, reception agreements have been completed with China, Norway, Singapore and the United Kingdom of Great Britain and Northern Ireland, and many others are under negotiation. Preliminary work is also beginning on RADARSAT II, the follow-on satellite.

As just one example of its many uses, RADARSAT undertook the Antarctic Mapping Mission (AMM), between 9 September and 3 November 1997, during which time the satellite completely mapped Antarctica at high resolution. The mission involved the 180 degree rotation of RADARSAT, the first time that such a manoeuvre has been accomplished by an Earth observation satellite, allowing the radar to image to the left of the satellite track instead of to the right and steering the radar beam up to cover the South Pole.

The mission has important significance for the scientific community because almost 70 per cent of the Earth's fresh water is contained in the Antarctic region and changes in that enormous reservoir directly influence world sea levels. The preparation of a high-resolution digital mosaic of the ice sheet and exposed portions of the continent will help to better understand why changes in the ice sheet occur, providing more insight into the effects of human activity and global warming on the rapid retreat of large portions of the shelves in the Antarctic Peninsula. Using the images taken by RADARSAT, scientists will be able to examine for the first time in history similar processes occurring across the entire continent.

RADARSAT continues to provide users around the world with the means to manage resources ranging from forests to minerals, survey both natural and man-made environmental disasters, predict crop yields of such things as rice and wheat, monitor maritime traffic to gauge fishing activities and protect national sovereignty, provide real-time information on polar ice flows to aid in ship navigation, and aid considerably in such activities as urban planning and land use mapping. A few examples of the many successful uses of RADARSAT data over the past year have included oil and gas exploration in Texas and South America, forest management in Indonesia, disaster assessment and monitoring after such incidents as the floods in Oregon and the North American Prairies or the oil spills off the coasts of Wales and Japan, rice crop monitoring in China, and the use of RADARSAT for sea ice navigation in Canada's north and the humanitarian crisis which unfolded in the great lakes region of central Africa. These applications, and many more, were demonstrated by users organizations from around the world at the highly successful conference Geomatics in the Era of RADARSAT, GER '97, held in Ottawa, Canada, in June 1997. The conference provided ample demonstration yet again of the utility of radar data, on its own or in concert with optical imagery, for a host of applications. The Government of Canada would like to thank Her Royal Highness, the Princess of Thailand, for opening the conference, as well as all nations that sent their experts and helped make the event a success.

C. Human space flight

Also important this past year were the activities of Canadian astronaut Bjarni Tryggvason on STS-85. As payload specialist aboard the United States space shuttle Discovery, Tryggvason's primary role was to confirm the capabilities of a vital piece of Canadian-made technology, the Microgravity Vibration Isolation Mount (MIM), ultimately destined for use aboard the International Space Station. MIM proved enormously successful at isolating experiments from high-frequency vibrations on orbiting space platforms, thereby improving the quality of experiment results.

Tryggvason also performed experiments designed by Canadian students, reflecting the commitment of both Tryggvason and CSA to use space exploration to inspire young Canadians to pursue studies and careers in science and technology. The crew also tested and used the latest version of the Canadian Space Vision System (CSVS).

Upcoming space shuttle missions will involve Canadian astronauts Julie Payette and Steve MacLean as mission specialists and Dave Williams as a payload specialist.

D. Space science

In atmospheric studies and global change research, Canada is participating in NASA's Mission to Planet Earth (MTPE) programme, with the Measurements of Pollution in the Troposphere (MOPITT) probe. Scheduled for launch during the summer of 1998, MOPITT will be Canada's first major instrument to monitor pollution of the Earth's atmosphere from space and will be launched onboard the first of NASA's Earth Observation System (EOS) satellites, which is the centrepiece of the MTPE programme. During the course of its five-year flight, MOPITT will continuously scan the atmosphere below it to provide the world with the first long-term, global measurements of carbon monoxide and methane gas levels in the lower atmosphere. Together with other measurements performed as part of MTPE, these data will help form the first long-term integrated measurements of the Earth's land, air, water and life processes. The database will be used by scientists to predict long-term effects of pollution, understand the growth of ozone in the lower atmosphere, and guide the evaluation and application of shorter-term pollution controls.

In atmospheric studies and astronomy, Canada is participating with Finland and France in the Swedish-led Odin satellite. The Canadian contribution to Odin is an Optical Spectrograph and Infra-Red Imaging System (OSIRIS) instrument, which will provide the world with its most detailed-ever data relating to ozone depletion. Previous satellite instruments have so far identified the existence and extent of the ozone problem, but OSIRIS will be the first to measure the concentration of ozone-depleting pollutants and to positively identify the human activities that contribute to the problem. The Odin satellite is scheduled for launch in autumn of 1998 and has a design lifetime of two years.

In space astronomy, Canada is participating in the Japanese-led VLBI Space Observatory Program (VSOP). VSOP consists of space and Earth-based antennae that can measure naturally occurring radio signals from space for the purposes of mapping detailed features of objects such as gas clouds and the magnetic fields of stars. By combining terrestrial and space antennae in this manner, a synthetic radio telescope will be created with an effective diameter of 35,000 km. With this massive resource, VSOP scientists will probe our galaxy, quasars and other galaxies with a resolution so clear as to be able to see a grain of rice in Tokyo from as far as Montreal. Canada developed a number of sophisticated digital-recording systems that have been installed at eight ground-based observatories and telemetry stations around the world in support of VSOP. Data will be captured by these recorders, correlated, calibrated, and made into raw images and detailed images by the scientific investigators. The measurements will be used alongside Japanese and United States correlative measurements to study features such as electrically charged gas clouds and the magnetic fields of stars and to construct new, detailed images of objects in the early universe whose rapid changes may help explain how the universe evolves.

Canada is also a participant in the FUSE (Far Ultra-violet Spectroscopic Explorer) programme, along with the United States and France, to create a space-borne astronomical spectroscope to observe the FUV wavelength region, which contains a wealth of yet unexplored astrophysical information. Lyman FUSE will use high-resolution spectroscopy to observe sources throughout our galaxy and at large extragalactic distances. Lyman FUSE will use high-resolution spectroscopy below the 1,200 nm Hubble Space Telescope limit to observe sources throughout our galaxy and at large extragalactic distances.

Finally, in life sciences, Canada participated with the Russian Federation and the United States in the SWIF (Sleep Wake Immune Function) experiment on the Russian MIR space station. This experiment helped determine the influence of gravity change on sleep wakefulness on the immune system of astronauts. Research in Canada is also ongoing on the VCF (Visuo-motor Coordination Facility) experiment for the NASA 1998 Neurolab mission, for which Canada contributed the flight hardware. Preparations are also under way for the second flight of the Aquatic Research Facility on the NASA shuttle in 1998.

Other examples of life science research in Canada include a significant new programme which will examine the mechanisms of bone demineralization during spaceflight and assist in the treatment of osteoporosis on Earth, as well as a cooperative programme between Canadian and Russian scientists on extended bed rest studies. These studies are providing considerable information not only for long-term space habitation but, more importantly to the general population, on muscle deterioration and metabolic changes in women after extended confinement in bed.

E. International cooperation

As in the past, international cooperation remained the cornerstone of Canadian activity in space during 1997. Canada has continued its fruitful cooperation in space with the United States, the European Space Agency, of which Canada has been a Cooperation State since 1979, and the Russian Federation, Japan and many other countries. It anticipates fostering and developing further linkages with partners around the world in the coming years.

Further information on Canadian space activities can be obtained from the following World Wide Web sites:

- The Canadian Space Agency (http://www.space.gc.ca);
- The Canada Centre for Remote Sensing (http://www.ccrs.nrcan.gc.ca);
- The Communications Research Centre (http://www.crc.doc.ca);
- The Government of Canada (http://canada.gc.ca).

CHILE

[Original: Spanish]

With regard to the space activities carried out in Chile in 1997, the following should be emphasized:

- Participation in the thirty-fourth session of the Scientific and Technical Subcommittee of COPUOS in Vienna from 17 to 28 February 1997, and in particular the presentation by Dr. Sylvia Sepúlveda of the University of Santiago of the CHAGASPACE experiment on the crystallization of proteins in microgravity conditions in the search for a cure for Chagas's disease;
- The holding of the First Latin American Seminar on Aerospace Medicine on 6 and 7 June 1997 at Santiago, sponsored by the United Nations Office for Outer Space Affairs;
- Participation in the meeting of the Legal Subcommittee of COPUOS in Vienna from 1 to 18 April 1997;
- Participation in the plenary meeting of the Committee for the Peaceful Uses of Outer Space in Vienna from 2 to 13 June 1997;
- Progress with the FASat programme, whose second scientific microsatellite, FASat Bravo, is ready to be placed into orbit in the near future with the participation of the Russian Space Agency. It is worthy of note that, in January 1997, a working visit was made to NASA's Goddard Space Center in connection with the

scientific support provided by NASA in the development of the Ozone Layer Measurement Experiment, OLME, which will be carried on board the FASat-Bravo satellite;

- Participation in the meetings for the study of the Agreement on Bilateral Cooperation on Space with the Russian Federation;
- Holding of a diploma course on air and space law at Santiago from 7 July to 30 August 1997;
- At governmental level, continuation of the study of the draft law on the establishment of the Chilean Space Agency;
- Further work on the project for a framework agreement on cooperation between Chile and Spain in the context of the development of a joint project on the construction of a minisatellite for the remote sensing of the Earth currently being studied so that a decision can be taken by both Governments;
- Visit to the United States by the Commander-in-Chief of the Air Force of Chile at the invitation of the Administrator of NASA, during which the following matters relating to the arrangements for joint cooperation were discussed:

  (i) The intention of the Administrator of NASA for NASA to be the first space agency to sign an agreement on cooperation with the Chilean Space Agency immediately after it has been established;
  (ii) Possible advice from NASA on increasing the capacity of the Chilean satellite tracking station;
  (iii) Probable participation of Chilean engineers in NASA research projects;
  (iv) Probable visit to Chile of NASA scientists and astronauts to participate in seminars on updating knowledge of space matters;
  (v) Agreement of the Administrator to attend the International Air and Space Fair to be held in 1998;
  (vi) Support for the initiative of the Air Force of Chile with regard to the establishment of a Latin American Space Agency through the creation of the Chilean Space Agency.

CUBA

[Original: Spanish]

Work has been done essentially on six projects presented to, and approved at, the Third Space Conference of the Americas, held in Uruguay from 4 to 8 November 1996, as follows:

- Empirical modelling of the ionosphere in the region of the Gulf of Mexico and the Caribbean for purposes of propagation of radio waves and navigation;
- Ionospheric changes during magnetic storms in the American sector;
- Quantitative determination of atmospheric humidity and temperature based on infrared and water vapour images from geostationary operational environment satellites;
- Development of an integrated method of forecasting the trajectory and evolution of tropical cyclones based on images from geostationary operational environment satellites;
- Application of remote sensing and geographic information systems for sustainable development of townships to the west of Havana;
- Crystallization of substances of scientific and technical importance under microgravity conditions.

The most important results are described below.

In projects 1 and 2, the planned work on Cuban data has been completed and an empirical model of the ionosphere has been developed for five levels of solar activity and evaluations made of storms or ionospheric changes during geomagnetic storms in the Cuban region. Although the study of the Mexican ionospheric data was begun, it was not possible to complete the work because the contacts arranged between the experts of the two countries did not take place.

In projects 3 and 4, relationships were found between dust clouds in the Sahara, the formation of tropical cyclones, and drought in the Caribbean and the Gulf of Mexico. An algorithm was developed together with methods of calculation for the construction of temperature charts for the ocean surface and the evaluation of the coastal zone colour scanner (CZCS) for the determination of the primary production of the ocean and the study of currents.

Cloud cover was studied to determine its role in the radiation balance and its effect on climatic change. Cloud cover and the thermal structure of the ocean surface were also studied for assessing oceanic climate on the basis of images from geostationary satellites. Measurements of radiation and evapotranspiration were improved, on the basis of images from geostationary and polar satellites, for use in agrometeorology.

In project 5, the geo-environmental study of the westernmost township of Havana was started, and encouraging results were obtained from the point of view of improving its territorial restructuring. Access to cosmic images is necessary if the work is to be completed.

Finally, in the field of basic space sciences, Cuba is coordinating with two Latin American countries (Colombia and Costa Rica) the joint observation of the solar eclipse of 26 February 1998 using radio waves and optical methods. The support of the Office for Outer Space Affairs for this Latin American initiative would be most useful.

INDIA

[Original: English]

India continues to make progress in the development and application of space technology for rapid socio-economic development of the country. Also, India continued to enhance the international cooperation in the exploration and peaceful uses of outer space.

A. INSAT system

The launch of INSAT-2D on 4 June 1997 by an Ariane launch vehicle and its successful testing and commissioning has enabled the country to further enhance the space services for its people. The INSAT system now comprising INSAT-1D, the last of the INSAT-1 series and four of the Indian-built INSAT-2 series, namely, INSAT-2A, INSAT-2B, INSAT-2C and INSAT-2D, is providing telecommunication, television broadcasting, meteorology, disaster management and search and rescue services.

INSAT-2C and INSAT-2D have enabled provision of new services like mobile satellite communication, corporate communication in Ku-band and extended coverage for Indian television broadcasting. The follow-on satellite in the INSAT series, INSAT-2E, carrying advanced meteorological payloads, in addition to communication payloads, is scheduled for launch in 1998 and 11 transponders on board this satellite are being leased to the International Telecommunication Satellite Organisation (INTELSAT).

INSAT system is used extensively by India for broadcasting educational programmes for schools and college students. A channel on the INSAT system has been exclusively dedicated for interactive training and developmental education. The two-year pilot project on satellite-based developmental communication which started on 1 November 1996, in the predominantly tribal district of Madhya Pradesh in Central India, is providing inputs for conceiving a nationwide satellite-based network for rural development.

B. Indian Remote Sensing Satellite systems

The four Indian Remote Sensing Satellites, IRS-1B, IRS-1C, IRS-P2 and IRS-P3 have been performing well and the data from these satellites is being received by India and also by ground stations in North America, Europe, Thailand and Taiwan Province of China. More stations are expected to receive the data soon. IRS-1D, the follow-on to IRS-1C, is slated for launch in September/October 1997 on board India's Polar Satellite Launch Vehicle, PSLV. IRS-1D, like its predecessor, IRS-1C, will provide high spatial and spectral resolutions, stereo viewing and on-board data recording capability. India has planned to launch three more remote sensing satellites, IRS-P4, IRS-P5 and IRS-P6 during 1998-1999 and 1999-2000 and 2000-2001 carrying payloads for oceanography, cartography and resources monitoring, respectively.

With the availability of a variety of data on a more repetitive basis from the increasing number of IRS satellites, India has been able to make further progress in using space-based remote sensing for applications like agricultural crop acreage and yield estimation, drought monitoring and assessment, flood mapping, landuse and land cover mapping, waste land management, ocean/marine resources survey, urban planning, mineral prospecting, targeting underground water and forest resources survey and management.

C. Integrated Mission for Sustainable Development

One of the important applications of IRS data in India is for the generation of locale-specific action plans under the Integrated Mission for Sustainable Development (IMSD), which was initiated in 1992. IMSD is coordinated by the National Natural Resources Management System (NNRMS) of the Department of Space and the mission now extends to selected areas in about 175 districts of the country. Implementation of the action plans generated under IMSD has also progressed well.

D. Launch Vehicle Technology

India has completed the development of Polar Satellite Launch Vehicle (PSLV) after two successful developmental flights, one in October 1994 and the other in March 1996. The first operational flight, PSLV-C1, is planned in September/October 1997 to place the Indian Remote Sensing Satellite, IRS-1D, weighing 1,200 kg, into its 817 km polar sun-synchronous orbit.

Substantial progress has been made in the development of a Geosynchronous Satellite Launch Vehicle (GSLV) for launching India's INSAT class of satellites. The first developmental flight test of GSLV is planned in 1998.

E. Progress in space science

The X-ray astronomy payload on board IRS-P3 and the gamma-ray burst detector and retarding potential analyser on board SROSS (Stretched Rohini Satellite Series)-C2 satellite are providing valuable data to the scientists. The National Mesosphere-Stratosphere-Troposphere near Tirupati, in southern India is benefiting the study of the characteristics of upper Earth atmosphere. To complement the International Geosphere Biosphere Programme, India has taken up several investigations with special reference to the processes that are relevant to the Indian subcontinent.

F. International cooperation

IRS-P3, carrying the Modular Opto-Electronic Scanner designed and developed by the German space agency, DLR, continues to provide data on ocean biota and other parameters. The first course on remote sensing has been successfully completed by the United Nations Asia-Pacific Regional Centre for Space Science and

Technology Education set up in India. The second course, which is on satellite communication, is scheduled to be completed on 22 September 1997. Under the Sharing of Experience in Space (SHARES) scheme of Department of Space, India has trained several personnel from developing countries in space communication and remote sensing. India continues to have cooperative agreements with space agencies of other countries for furthering the exploration and peaceful uses of outer space.

G. Conclusion

The successful launch and operation of INSAT and IRS series of satellites have enabled India to enhance and improve the space services in vital areas like telecommunication, television broadcasting, meteorology, disaster warning, search and rescue, mobile communications and resources survey and management. The successful completion of the development of Polar Satellite Launch Vehicle (PSLV), has made India self-reliant for launching its IRS class of satellites. The planned launches of follow-on satellites in the INSAT and IRS series will provide further stimulation to the space services in the country.

INDONESIA

[Original: English]

Space activities in Indonesia started in the early 1960s. Initially, space activities focused on rocket research and development. In 1963, sounding rockets built by Indonesia and Kappa rockets (bought from Japan) had been successfully launched from Pameungpeuk rocket launching station located in West Java. Scientific data obtained by rockets had been provided to IQSY (International Quiet Sun Year) programme 1964-1965. The space activities were suspended for a few years till 1970 due to the political situation in the country but have grown more important ever since. Since 1970, space activities continue to increase within the broader spectrum focused on space applications. Programmes related to space science and technology intensified since 1980, including R & D efforts, stressed in support of space applications. The following sections will describe Indonesia's space policy and highlight progress in its space programme.

A. Indonesia's space policy

Since space technology applications play a great role in promoting sustainable development, in 1993 the Indonesian national space development programme was firmly spelt out in the Guidelines of State Policy, a five-yearly general pattern of national building made by the Indonesian People's Assembly Council. Emphasis of the national space development has been focused on the space technology applications to raise the welfare of all the people of Indonesia, on the acquisition and mastery of space science and technology, and on human resources development. One essential aspect of this national space development programme is cooperation with other countries.

The direction contained in the Guidelines of State Policy has put the space programme at a high priority in the national development programme. This priority is also delineated by a constellation of national organizations regarding space activities. Indonesia has a council, namely the National Council for Aeronautics and Space of the Republic of Indonesia (DEPANRI). The council functions as the highest national coordination and general policy formulation forum in the country for space development. The Chairman, Vice-Chairman and Secretary of the council are the President of Indonesia, the Minister of State for Research and Technology, and the Chairman of the National Institute of Aeronautics and Space (LAPAN), respectively. While its members consist of the Minister of Foreign Affairs, the Minister of Defence, the Minister of Industries and Trades, the Minister of Communications, the Minister of Tourism, Post and Telecommunications, and the Minister of State for National Development Planning/Chairman of the National Development Planning Board (BAPPENAS). Space and space-related activities are conducted by various Departments and Agencies concurrent with their functions and

interests. Space activities dealing with research and development carried out by Departments and Agencies are technically coordinated by the Minister of State for Research and Technology.

Based on the priority of national development programmes, the activities are directed primarily to develop applications of space technology. Activities regarding space technology and space science are directed to support the development of space applications and industrial activities.

Recently, there has been significant growth of involvement of the private sector in the space business. The Government of Indonesia will continue to foster the growth of the private sector in the commercial use of space.

In providing the firmer ground for the nation in conducting ever-increasing space activities in the future, Indonesia is now undertaking to formulate "Indonesia's Outlook on Space" and a "General Policy on Space Development until the Year 2010". Based on that outlook and policy, the main elements of Indonesia's space programme include:

- Human resources development;
- Space science and technology development;
- Space industry development;
- Space-based service industry development;
- Space-based natural resources management;
- Political and legal development on space;
- Space institution development.

These seven elements should be delineated in the activities of any space programme conducted by Indonesia. By doing so, it is expected that Indonesia will be able to achieve a self-sustaining capacity in overall space activities before the year 2010.

B. Indonesia's space activities

1. Satellite communication applications

For telecommunication services (fixed communications, TV and radio broadcasts) throughout the country, Indonesia since 1976 has operated its own domestic PALAPA satellites. At present, six domestic satellites are being operated, which consist of four satellites of PALAPA B series and two satellites of PALAPA C series launched on 1 February 1996 and 16 May 1996, respectively. Antenna coverage of PALAPA C series for the purpose of fixed telecommunications and direct TV broadcasting cover most of the Asia and the Pacific region. With support of telecommunication services provided by satellites, it is expected that by the end of the Sixth Five-Year Development Plan (up to March 1999) there will be 4.2 telephone lines per 100 people.

The other important benefit of using satellites in the country is to speed up the coverage of education especially in remote areas at the level of the university. Already for some years, Indonesia has conducted education programmes through satellites, by which students attend classes in their own homes or classrooms.

The existence of PALAPA, which makes a big leap in serving telecommunication needs, has also driven the growth of various telecommunication equipment, cables and exchange/switching industries. Even the Nusantara Aircraft Industries (PT.IPTN), a state-owned company, is undertaking efforts to enhance its capabilities in producing certain components of the next generation satellites of PALAPA series.

Policies and strategies concerning space communication development in the country is handled and coordinated by the Ministry of Tourism, Post and Telecommunications. In line with the national policy, the Indonesian Government continues to encourage the private companies to partake in the responsibilities of

providing satellite communications. At this time, apart from the State-owned companies like PT.Telkom, PT.Indosat and PT.Satelindo, a number of private companies are partaking in operation and provision of satellite communications. These private companies include PT.Pasific Satelit Nusantara (PSN) of Indonesia and PT. Media Citra Indostar. The involvement of private companies in the space communication sector will continue to increase. PSN of Indonesia, in cooperation with Jasmine International Overseas Corp of Thailand and Philippine Long Distance Telephone (PLDT) of the Philippines, is carrying out a joint project, namely the Asia Cellular Satellite (ACeS) Project. This project aims at launching Garuda-1 and Garuda-2 satellites at the beginning of 1999. The satellites are intended to function as the Global Mobile Personal System (GMPCS) for the Asia and the Pacific region.

2. Remote sensing

Remote sensing technology has played a significant role in natural resources management and environment assessment in Indonesia. Model and application methodologies developed through R & D activities on remote sensing have been applied by users from various sectors, especially those involved in directing and executing national development policy for natural resources and environment management. The ground station located in Parepare, South Sulawesi, has been operated more than three years to acquire and record data transmitted by various satellites such as Landsat-5, SPOT-2, and ERS-1.

In 1995, the capability of a remote sensing ground station system described above has been advanced by the establishment of the JERS-1 ground station system in cooperation with NASDA-Japan. This system is also designed to be able to operationally receive, record and process OPS and SAR data in standard formats.

Indonesia is also developing Integrated Priority Researches in the field of remote sensing technology. These priority researches are organized by the National Research Council. The purpose of this priority research programme is to integrate various researches which refer to the main national programme in Research and Technology. This programme includes various research institutes under the State Ministry of Research and Technology, the National Research Council and the National Development Planning Board.

Many institutions, agencies and ministries in Indonesia have been involved in remote sensing activities. Based on its functions, the National Institute of Aeronautics and Space (LAPAN) acts as national focal point in the development of remote sensing satellite technology and its applications in the country. In this relation, LAPAN operates the remote sensing ground station system as well as other facilities for the purpose of remote sensing satellite data applications. The other national agencies, among others, the National Coordination Agency for Surveying and Mapping (BAKOSURTANAL), the Agency for Assessment and Application of Technology (BPPT), the Indonesian Institutes of Sciences (LIPI), the Ministry of Public Works and the Ministry of Forestry have also installed data-processing facilities concurrent with their needs. Higher learning institutes, among others, University of Gadjah Mada (UGM) and Bogor Agriculture University (IPB), have established and carried out education and training programmes in remote sensing. The programme is aimed at developing students as both scholars and skilled practitioners in the applications of space remote sensing data.

Operational applications of remote sensing data mentioned above has pushed the private sector to become involved in supplying required spatial information, hardware and software of processing facilities and its accessories, and in supplying any required information for developing the GIS system.

3. Satellite meteorology

Indonesia established its first meteorological satellite ground receiving station at Jakarta in 1978. It was designed to receive both GMS and NOAA satellite data. A second station was later installed in Irian Jaya to cover the eastern part of the country. The use of these data for non-meteorological purposes started in 1987 with the development of applications in forest fire detection and monitoring, drought monitoring, crop assessment and sea

surface temperature mapping. Recent research has focused on the development of an early warning system for forest fire, drought monitoring and determination of its relationship with rice production, monitoring of the movement of the intertropical convergence zone (ITCZ), the development of a model for El Niño Southern Oscillation (ENSO) prediction and its impact on crop production as well as flood assessment and monitoring.

During the dry season which fell for a long period of time in 1997, satellite data have a great role in detecting hot spots in various areas of Indonesia. Based on the detected hot spots, appropriate actions have been taken in mitigating forest fires.

Many institutes and agencies are involved in meteorological satellite data applications. LAPAN operates ground station systems to receive satellite data and also conducts activities concerning methodology development for furtherance of data applications. Others mainly focus their activities on the use of satellite data for their specific needs.

4. Space technology development

Programmes related to space technology development and space research intensified since 1980 and, including R & D efforts, have been stressed for the indigenous design and development of systems and/or subsystems. Such systems include those for guidance and control, sounding rocket mechanism and structures, development and testing of propellant raw materials and solid propellant, space vehicle payload and telemetry technology, data communication and low Earth orbit tracking technology. LAPAN is the main institute focusing its efforts in space technology development. Currently, LAPAN is developing the standardized meteorological rockets for the purpose of researches dealing with middle and upper atmospheric physics.

5. Space research

Space research activities are conducted by various agencies and institutes in the country in accordance with their functions. The main institute undertaking space research activities is LAPAN.

The general objectives of LAPAN activities on space research are to understand the natural phenomenon of aerospace and its specifications in relation to Indonesian climate prediction and environmental conditions. Specifically, the objectives include :

- Indonesian climate modelling;
- Ozone, greenhouse gases and air pollution distribution modelling (above big cities);
- Determining the advantage of ionospheric behaviour for radio communications and navigation.

In support of its activities, LAPAN has installed and operated a number of facilities. These include ground-based equipment, meteorological stations, stations for balloon launching, stations for rocket launching, an atmospheric chemistry laboratory, stations for ionospheric research, and a laboratory and software for climate modelling, in particular Indonesian climate modelling.

In achieving the above-specified objectives, LAPAN has conducted various activities comprising atmospheric research, ozone observations, air pollution monitoring, and research on solar physics, the solar-terrestrial relationship, the ionosphere and the upper atmosphere.

(a) Atmospheric research and climate modelling

The main purpose of atmospheric research is to gain better understanding of behaviour of weather and climate elements, physical, dynamical, and thermodynamical processes in the atmosphere. The effect of atmospheric phenomenon on weather and climate variations is also important to be known. There has been a

tendency of changes in weather/climate elements especially in the surface temperature and relative humidity in the early 1990s in big cities such as Jakarta and Bandung.

The physical process (dynamical and thermodynamical process in microscales) is strongly related to cloud and rain, as in the convection process. Research on the physical process has been undertaken with the purpose of obtaining more information about the convection process occurring in the Indonesian region. This research has resulted in information on the development of cloud convection for the regions of Serpong, Bandung and Biak through the one-dimension convection model and its comparison with the Boundary Layer Radar data. The atmospheric phenomena such as ENSO and El Niño were also analysed so as to know the effects of the phenomenon on the weather/climate variations.

In anticipating the effects of climate change and air pollution, LAPAN has been preparing the steps to use climate modelling and pollution distribution for simulation, scenario and climate prediction with the capability of predicting floods, long dry seasons and increases in surface temperature. All this information results in an improvement of policy for the planting season.

Climate research was focused on using the climate modelling such as the Global Circulation Model (GCM) and the Limited Area Model (LAM). Dynamically and physically, both models use a similar theory. The use of LAM is aimed at making more detailed climate simulations for certain regions which cannot be done by GCM due to its limited resolution. The condition of this LAM was taken from the results of GCM simulations.

The climate scenario is based on simulation by using certain assumptions about the future, for example that in the middle of the twenty-first century, the CO_2 concentration would double, or the solar activity would increase by 1 per cent, in order to predict the climate conditions based on those assumptions. To a certain extent of accuracy, a prediction model of the weather and climate of Indonesia has been developed. The outputs of the model complement conventional observations.

(b) Ozone observations

LAPAN has been showing the international issue of ozone depletion great attention lately. In this connection, LAPAN has been undertaking measurement and research on total, profile and surface conditions of ozone.

(c) Air pollution monitoring

The purpose of air pollution monitoring is to obtain data on the quality of air above some big cities of Indonesia. Various efforts concerning observation and research on some trace gases and aerosol as well as their impacts on the quality of rain water have been carried out.

(d) Research on solar physics, the solar-terrestrial relationship and the ionosphere and upper atmosphere

Research on solar physics has mainly contributed to the development of the weather and climate model and ozone observations, while research on the solar-terrestrial relationship has been mainly intended to complement ozone observations and establish the advantage of the ionosphere for radio communications and navigation. Certainly, the research on the ionosphere and upper atmosphere has contributed to the understanding of the ionospheric advantage for radio communications and navigation.

Research on solar physics

In the field of solar physics, the sunspot number has been observed from the solar observation station at Watukosek (7.57° S, 112.65° E) and Sumedang (6.5° S, 107.47° E), while the solar radio burst has been observed

from Sumedang by using radio spectrography. The observational data have been used in supporting frequency prediction for HF radio communication.

The simulation of turbulence in CME (Coronal Mass Ejection) was developed in 1996. The simulation showed the reconnection of the magnetic field in one foot of the loop's. Other than turbulence, the simulation showed some events produced by the interaction time-dependent non-linear model, such as the formation of wave-front pressure and a weak shock-front around the disturbed coronal magnetic field.

A model describing the structure and activities of the sun is now under development within the LAPAN Climate Programme. The main objective is to obtain a model for the variation of solar output which can be used as an input for GCM. The preliminary results by adding mass-loss effect on a standard model showed that the temperature during the evolution of the sun in 5 billion years will be lower than that predicted by the standard model.

Research on the solar-terrestrial relationship

The possible relation between solar variability and total ozone over Indonesia has been studied on the basis of data obtained by the Total Ozone Mapping Spectrometer (TOMS) on board Nimbus Satellites during the period October 1978-December 1992. Data used in this study represented the region between 7° S and 7° N, and between 95° E and 140° E. The total ozone variation was clearly dominated by two effects with a periodicity of 22-34 months and amplitude in the order of 8 per cent (~20 Dobson units). The residual time series obtained after removing those two effects indicated the presence of an 11-year variation in phase with the oscillation of solar activity in the same period.

By analysing the available complete data of surface air mean temperature of Padang and Jakarta in Indonesia during 1974-1989 and comparing with data on the sunspot number, an indication of the effect of solar activity on surface air temperature, especially in dry seasons, has been shown. In 1976 and 1986 the temperature tended to decrease in accordance with minimum solar activity. The influence of El Niño, which warmed the atmosphere during those years, caused the temperature not to reach the minimum. However, in 1989 the temperature, which was supposed to be maximum in accordance with maximum solar activity, decreased. This may be due to La Niña 1988/1989. Solar activity and El Niño/La Niña, at least, seem to be dominant factors affecting surface air temperature in Indonesia.

Research on the ionosphere and upper atmosphere

The ionospheric vertical incidence soundings are routinely performed at Sumedang (6.5° S, 107.47° E), Pameungpeuk (7° S, 107° E), Pontianak (0.02° S, 109.20° E) and Biak (1.1° S, 136.05° E). The results of soundings were used to develop frequency prediction for HF radio communication in Indonesia. The forecasts published every year have been distributed to potential users, mainly provincial government offices and regional offices of the Ministry of Health.

Medium frequency (MF) radar has been in full operation at Pontianak (0.5°, 109.1° E), West Kalimantan, as a collaborative project between LAPAN (Indonesia), the University of Adelaide (Australia) and Kyoto University (Japan). By using 1.98 MHz frequency with the power of 25 kilowatt, the three antennas of MF radar observe the two components wind up to a 60-100 km high in the day time and a 70-100 km high in the night, every 2 km with a time resolution of two minutes. The analysis of the observational data during November 1995-September 1996 has shown that zonal and meridional winds at a height of 78-98 km reached the maximum velocity (more than 50 m/s) during the equinox (March and September) in the direction of West and South, respectively. In the mesosphere/lower thermosphere it was found from spectral analysis that there was some periodicity: the longer one of 2 to 10 days and the shorter one of 5 minutes to 24 hours. Such findings indicate the existence of Kelvin waves (longer period) and tides and gravity waves (shorter period).

6. Studies on socio-economic and legal aspects

Besides the technical aspect as already mentioned, the socio-economic and legal aspects of space activities are also a major concern in the country. Studies concerning various socio-economic and legal aspects of space activities on the national and international spheres are being conducted to set a firmer base for future space activities in Indonesia. In 1996 and 1997, Indonesia ratified the Liability Convention, 1972 and the Registration Convention, 1976, respectively. Indonesia is now considering the possible ratification of the other international space treaties. These efforts are promoted and organized by LAPAN as a focal point and Secretariat of DEPANRI.

C. Regional and international cooperation

Regional and international cooperation in the field of space activities are considered of high importance to speed up the process of the transfer of technology as well as to promote the peaceful uses of outer space. Indonesia also realizes that the progress of space science and technology and their applications have proven its benefits for all mankind. Therefore, Indonesia has cooperated with many countries and also actively participated in regional and international events. Indonesia always participates in the main events and meetings with regard to space, among others:

- Regional Space Applications Programme for Sustainable Development in Asia and the Pacific (RESAP);
- European Community/Association of South-East Asian Nations (ASEAN) projects;
- Asia-Pacific Regional Space Agency Forum,
- Asian Regional Satellite;
- ASEAN Expert Working Group on Remote Sensing;
- Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP);
- Asia-Pacific Network for the Global Change Research (APN);
- Global Research Network System (GRNS);
- SARCS-START/International Geosphere/Biosphere Programme;
- International Astronautical Federation;
- Committee on Space Research;
- Committee on the Peaceful Uses of Outer Space.

D. Future programmes

Indonesia's space programmes in the future will still be focused on space applications to meet the national needs. The applications of space communication satellites, remote sensing satellites and meteorological satellites still constitute the main parts of Indonesia's space programme. Nevertheless, in line with the national development programme, Indonesia will increase its efforts in development of space technology in order to achieve self-sustaining capacity in the overall space activities. To this end, Indonesia is developing its own Aeronautical Navigation Satellite System (ANSS). It is planned that ANSS will be launched in the first decade of the twenty-first century. In the development of ANSS, Indonesia cooperates with DASA (Germany) and the Hughes Corporation (United States). The service area of ANSS will cover the overall area of Indonesia and a small part of the Asia and the Pacific region. Indonesia is also seriously considering the establishment and operation of a spaceport within the territory of Indonesia. Besides, Indonesia is undertaking studies on the possibility of its own remote sensing satellite in the future, taking into account the specific needs and particular geographical conditions of the country.

E. Conclusion

The experience and expertise achieved by Indonesia in the field of space are offered to be shared with other countries based on mutual benefits and common interests.

In line with its ever-increasing space activities, Indonesia will continue its efforts to promote cooperation with other countries in the exploration and use of space for peaceful purposes.

ITALY

[Original: English]

The Italian Space Agency (ASI), established in 1988, has the responsibility:

- To promote, coordinate and manage national programmes and bilateral and multilateral cooperation programmes;
- To promote and support Italian scientific and industrial participation in the European Space Agency (ESA) programmes, in harmonization with national programmes.

A. The National Space Plan (PSN)

A National Space Plan (PSN) has been established to promote, support and control a coordinated programme for scientific, technological and commercial applications of space activities as well as to promote new technological capabilities in the Italian aerospace industries.

The PSN is defined by the Italian Space Agency on a five-year basis, with annual updating, for the approval of the Ministry of Education and Research and final endorsement by the Inter-ministerial Committee for Economic Planning (CIPE).

The next national space plan will cover the period 1998-2002.

1. Budget

In 1996, the Italian civil budget was approximately 600 million United States dollars (US$), shared between ESA and national activities. In 1997, it will reach approximately US$ 680 million with a trend to further increase in the coming years. A 15 per cent of the budget is generally allocated to scientific research.

2. Scientific research

ASI allocates each year 500 initiatives concerning research activities as well as development activities for payloads to be embarked on scientific satellites. Subjects involved are: universities, the Italian National Research Council, observatories, public research organizations, joint ventures between universities and national industry. Investigation fields covered are: universe sciences, earth sciences, life sciences and engineering sciences.

B. Major national programmes

1. Scientific programmes and interplanetary missions

(a) Tethered satellite system (TSS)

Cooperative programme with NASA to study the interaction between the system (satellite conductive tether-deployer in the space shuttle's cargo bay) and the Earth's ionosphere. The two missions (TSS 1 in July 1992 and TSS 2 in February 1996) validated the TSS dynamics and with the second mission the possible use of the system for the conversion of orbital energy into electrical energy has been confirmed. Future applications, also connected with the International Space Station and with a possible atmospheric mission, are under study.

Three Italian astronauts have been flown during the TSS missions: Franco Malerba (ASI) in 1992, as payload specialist, and in 1996, Umberto Guidoni (ASI) as Payload Specialist and Maurizio Cheli (ESA) as mission specialist.

(b) LAGEOS II

The laser geodynamics satellite LAGEOS II was built to improve on the previous NASA LAGEOS I satellite's performance using laser ranging experiments to, through a global network of observatories, the Earth's crust movement. It was developed in cooperation with NASA and launched from the space shuttle by the Italian IRIS upper stage in October 1992. The satellite has a diameter of 60 cm and a weight of about 409 kg; it is in a 6,000 km circular orbit with an inclination of 52 degrees. Its surface is covered by 426 reflectors to return the laser light back to the observatory.

(c) Beppo-SAX

The X-ray astronomy satellite Beppo-SAX, named in honour of Giuseppe Occhialini, one of the founders of cosmic ray physics, was developed in cooperation with the Dutch Space Agency (NIVR) to perform spectroscopic, spectral and time variability studies of celestial X-ray sources in the energy band from 0.1 to 300 KeV. Launched in April 1996, it has made an important contribution toward solving one of astronomy's greatest enigmas by detecting for the first time X-ray emission from the source producing a gamma ray burst, thus allowing astronomers worldwide to watch the fading visible light counterpart of the gamma ray burst. SAX is a 1,400 kg satellite in an equatorial 500 km circular orbit.

(d) SAC-B

SAC-B is a scientific satellite developed for the study of solar physics by the Argentine Space Agency (CONAE) in cooperation with NASA and ASI. ASI provided the solar panels equipped with GaAs cells and the scientific instrument ISENA (Imaging Spectrometer for Energetic Neutral Atoms). SAC-B was launched in 1996.

(e) Ultraviolet Spectrograph Telescope for Astronomical Research (UVSTAR)

UVSTAR is an instrument of the International Extreme-Ultraviolet Hitchhiker (IEH-01), which has flown on board the space shuttle twice, in September 1995 and August 1997. A third flight is at present foreseen for October 1998.

The Italian ultraviolet telescope has been developed within the framework of cooperation between ASI and NASA, for the study of EUV emissions.

(f) Solar and Heliospheric Obsevatory Mission (SOHO/UVCS)

SOHO/UVCS, a project of international cooperation between ESA and NASA was launched in December 1995. It will study the Sun and its interaction with the Earth and, with its sophisticated instruments, will observe in particular the structure of the solar interior, its atmosphere and the dynamics of coronal plasma. ASI, in a cooperative agreement with NASA, developed the Ultraviolet Coronograph Spectrometer (UVCS), one of the most important instruments for studying the solar corona and the solar wind.

(g) CASSINI/HUYGENS

CASSINI/HUYGENS is an interplanetary NASA/ESA/ASI mission for the study of Jupiter and its moon Titan. The mission began in October 1997 and, after a seven-year journey, the CASSINI spacecraft with the HUYEGNS probe will reach Saturn in 2004 and explore the planet and its moons for four years.

Under an agreement with NASA, ASI has developed the High Gain Antenna, the radio frequency system for the Radio Science Subsystem (RFIS), the CASSINI Radar RF experiment (RFES) and the Visual Infrared Mapping Spectrometer (VIMS). ASI has also developed the HUYGENS Atmospheric Structure Instrument (H-ASI) for measuring the physical and electrical properties of Titan's atmosphere.

(h) Central European Satellite for Advanced Research (CESAR)

A definition study has been carried out to develop, in cooperation with central European countries, a scientific satellite for the study of the atmosphere.

2. Telecommunications

(a) ITALSAT F1 and F2

ITALSAT F1 and F2 provide a domestic pre-operational communications system operating with a sophisticated payload working at 20/30 GHz (Ka band) with an on-board regeneration and commutation. The first satellite, Italsat F1, launched in January 1991, operated in the national public communication network until the launch of Italsat F2.

Italsat F1 propagation data are still being studied by national and international scientific experimenters. Italsat F2, launched in August 1996, completed the communications system with mobile communications. Its Ka band payloads will allow multimedia applications. The satellites each have a mass of about 2,000 kg (at launch) and are placed in geostationary orbits at 13 degrees East (F1) and 16 degrees East (F2).

3. Earth observation

(a) X-SAR

A cooperative programme with the German Space Agency (DARA) and NASA to develop an X-band synthetic aperture radar, X-SAR was flown (April and September 1994) on board the space shuttle with the Spaceborne Imaging Radar-C (SIR-C) as part of the Space Radar Laboratory (SRL) for multispectral radar observations. The two missions were dedicated to perform accurate remote sensing observations of the Earth and its environment and data collected are still being studied by the national and international scientific community.

A third mission, called SRTM, Shuttle Radar Topography Mission, for topographical mapping is planned for September 1999.

(b) SKYMED-COSMO

A constellation of small satellites at low orbit, equipped with optical and radar sensors for all weather and day/night observations, short revisit intervals of target areas, high spatial resolution and fast data recovery to users is planned. The initial system definition study is being carried out.

It will be designed to provide high-quality products to satisfy the need of the Mediterranean basin and other users for applications such as: civil protection, environmental monitoring, disaster monitoring, agricultural monitoring, cartography and mapping, urban monitoring, coastal monitoring and hydrological resources monitoring.

4. Space transportation

(a) IRIS

The upper stage is used in conjunction with NASA's space shuttle to place payloads up to 900 kg into geotransfer orbit. It was used in 1992 to place the satellite LAGEOS II in a 6,000 km circular orbit.

(b) Launcher

A feasibility study is being carried out to develop a launcher for satellites of up to 1 tonne into low Earth orbit.

5. International Space Station

(a) Mini Pressurized Logistic Modules (MPLMs)

According to a Memorandum of Understanding between ASI and NASA, Italy will develop three units of the Mini Pressurized Logistic Module. MPLM is the only pressurized logistic element of the space station able to transport, back and forth from the space station, food, supplies and experiments (up to 9,000 kg) in a conditioned environment. It flies inside the shuttle cargo bay and when docked to the station, it can stay up to 16 days for each mission providing a habitable environment for 2 crew members. It can accommodate up to 16 removable racks and weighs, fully loaded, about 13,700 kg. Each unit can fly up to 25 times over a ten-year period and will support the space station logistics in both the assembly and utilization phases.

(b) Nodes 2 and 3

Development, under an ESA/ASI agreement, of Nodes 2 and 3 that will be used to interconnect elements of the International Space Station.

6. Automation and robotics

In the framework of the SPIDER (Space Inspection Device for Extravehicular Repair) for the development of a free-flying robot for automated servicing and maintenance of space structure, currently under study, the following activities have been carried out.

(a) SPIDER manipulation system

This will fly on the MIR station in the last quarter of 1998 in the joint ESA/ASI/RSA-Energia JERICO (Joint European Robotics In-orbit Calibration Operation) mission.

(b) SD2

The drill, sample and distribution system is to be flown on the Rosetta Lander in 2003, to improve the scientific results of the landing on the Wirtanen Comet surface.

7. Space technology

Coordinated initiatives have been finalized to promote and develop national industrial technologies and related applications. The major technological initiatives developed are in the fields of electric propulsion, materials and components for traditional propulsion, millimetric waves (30-100 GHz), optoelectronic sensors, photovoltaic cells (GA As) and a specified integrated platform for attitude control and OBDH system (PICS).

C. Participation in European Space Agency Programmes

Italy was an early member of the European Space Organizations ELDO (European Launcher Development Organization) and ESRO (European Space Research Organization) and was one of the founders of the European Space Agency (ESA) (1975). With approximately 15 per cent contribution to ESA's total budget, Italy is the third member country after France and Germany.

Major participation is in the following projects.

(a) Scientific programmes

Significant Italian scientific and industrial involvement in the Horizon 2000 programmes, and in particular:

- SOHO (Solar and Heliospheric Observatory): designed to observe the sun from its deep interior to its outer regions and the solar wind;
- Cluster II: a cluster of four satellites to explore the Earth's magnetic and electric surroundings;
- ISO: Infrared Space Observatory for infrared astronomy;
- XMM (X-ray Multi-Mirror): for X-ray spectroscopy of cosmic objects;
- Integral (International Gamma-ray Astrophysical Laboratory): to observe and analyse cosmic gamma-ray sources;
- Rosetta: to rendezvous with the P/Wirtanen Comet.

(b) Telecommunications

- ARTEMIS/DRS (Data Relay Satellite System for In-orbit Communications): ARTEMIS is planned to be operative to serve the first Envisat 1 mission (units, subsystems and system contribution);
- EMS: L band mobile communications payload which flew on Italsat F2.

(c) Earth observation

- ERS 1/ERS 2: remote sensing satellites (GOME (ozone) and radar altimetry experiment contribution);
- Envisat 1: Earth observation mission devoted to the observation of the environment (microwave radiometer and radar altimeter contribution);
- Polar platform: development of a polar platform to be used for the Envisat and Metop missions;
- Meteosat: second generation development in cooperation with EUMETSAT of a new generation of Meteosat satellites for meteorological applications (units and subsystems contribution).

(d) Space transportation

- Ariane 5: development of an improved generation of the Ariane launcher (the solid boosters and first stage turbopump contributions);
- FESTIP: technological study for future reusable launch system.

(e) Manned space programme

International Space Station (ISS)

A European participation programme in the International Space Station for:

- COF (Columbus Orbital Facility): a pressurized module (structure, thermal control, subsystems and systems contributions);

- ATV (Automated Transfer Vehicle): to be integrated in the Ariane-5 launcher;
- CRV (Crew Rescue Vehicle)/CTV (Crew Transport Vehicle): system definition study.

D. ASI ground infrastructure

- Centro di Geodesia Spaziale "Giuseppe Colombo" in Matera for space geodesy, remote sensing and robotics;
- I-PAF (a multimission facility for archiving, processing and distributing remote sensing data), located at ASI/CGS, Matera;
- Stratospheric Balloons Launch Site facility, located in Trapani, Milo (Sicily) for long-duration flights on the Mediterranean Sea;
- ALTEC (ASI Logistic and Technological Engineering Center), Turin: a ground facility for engineering support to MPLM (ASI), COF/Columbus Orbital Facility and ATV/ Automated Transfer Vehicle (ESA);
- SAX Scientific Data Center, Rome: the main interface between the project and the scientific community.

Table. Launch dates of satellites with Italian participation

Name	*Launch vehicle*	*Site/date*
Italsat F1	Ariane	Kourou 15 January 1991
TSS-1	STS-46	Cape Canaveral 31 July 1992
LAGEOS II	STS-52/IRIS	Cape Canaveral 22 October 1992
X-SAR	STS-59	Cape Canaveral 09 April 1994
X-SAR	STS-68	Cape Canaveral 30 September 1994
UVSTAR I	STS-69	Cape Canaveral 07 September 1995
TSS-1R	STS-75	Cape Canaveral 22 February 1996
Beppo-SAX	Atlas	Cape Canaveral 30 April 1996
Italsat F2	Ariane 4	Kourou 08 August 1996
SAC-B	Pegasus	Wallops Island 04 November 1996
UVSTAR II	STS-85	Cape Canaveral 07 August 1997
Cassini/Huygens	Titan 4B	Cape Canaveral 15 October 1997
UV-STAR	STS	1998
MPLM 6A	STS	June 1999
MPLM UF1	STS	1999
MPLM UF2	STS	1999
MPLM UF3	STS	2000
CESAR	TSIKLON	2000

JAPAN

[Original: English]

The Japanese organization for national space activities and international cooperation is described in detail in the previous report (A/AC.105/661). Therefore, the present report concentrates on the current status of the development of space science and technology in Japan.

A. Lunar and planetary exploration

1. LUNAR-A Project (Moon Penetrator Mission)

ISAS plans to send a spacecraft called LUNAR-A to the Moon in 1998. It will be the third flight of the M-V vehicle which was developed by the Institute of Space and Astronautical Science (ISIS). LUNAR-A will drop three penetrators onto the Moon. The penetrators are supposed to penetrate the lunar surface and form a network that will explore the internal structure of the Moon by using on-board seismometers and heat flow meters.

2. PLANET-B Project (Mars Atmosphere/Plasma Mission)

PLANET-B is the first Japanese Mars mission and is scheduled in 1998 by the second launch of the M-V rocket. It will be injected into orbit around Mars, and will study the Martian upper atmosphere, especially its interaction with the solar wind.

3. MUSE-C Project (Asteroid Sample Return Mission)

MUSE-C is a sample return mission of 4,660 Nereus, a near-earth asteroid which seems to be one of the most primitive bodies in our solar system.

4. Projects under discussion

The following are among the lunar and planetary missions under discussion by ISAS: Comet Coma Sample Return Mission, Mars Rover Mission and Venus Aerocapture/Balloon Mission.

B. Astrophysics

1. Projects in the ASTRO series (satellites for astronomical observations)

The fifth X-ray astronomy satellite (ASTRO-E) is now being developed for launch in 1999. An infrared astronomy satellite is being developed for launch in 2002. In infrared astronomy, observations from stratospheric balloons and sounding rockets have been conducted. Observations from the Space Flyer Unit launched in March 1995 were carried out.

2. VLBI Space Observatory Programme

A satellite for very long baseline interferometry from space, called HALCA (Highly Advanced Laboratory for Communications and Astronomy), was launched by ISAS in February 1997. It was the first flight of the M-V vehicle that was developed by ISAS.

C. Communications

The N-STAR communications satellites (N-STARa/b) procured from the United States by Nippon Telegraph and Telephone were launched in August 1995 and in February 1996 to maintain the satellite communication services provided by CS-3.

The JCSAT communications satellite (JCSAT-3) produced by Japan Satellite Systems Inc. was launched in August 1995 to provide the satellite communication services.

D. Broadcasting

As to broadcasting satellites, the first launched BS-4 satellite (BSAT-1a) produced by the Broadcasting Satellite System Corp. was launched by Ariane rocket in April 1997, and provides the satellite broadcasting service replacing BS-3 in August 1997.

As to communication satellites for broadcasting, JCSAT-4 produced by Japan Satellite Systems was launched by Atlas rocket in February 1997 and is scheduled to begin digital broadcasting service in April 1998. Moreover, SUPERBIRD-C produced by Space Communications Corp. was launched by Atlas rocket in July 1997 and is scheduled to begin digital broadcasting service from November 1997.

E. Research and development satellites for communications and broadcasting technology

1. Communications and broadcasting Engineering Test Satellite (COMETS)

The objectives of COMETS are to develop and experimentally demonstrate new technologies of advanced satellite mobile communications, inter-orbit communications and advanced satellite broadcasting. The satellite weighs about 2,000 kg and is scheduled to be launched by the H-II launch vehicle into the geostationary orbit in the beginning of 1998.

2. Optical Inter-orbit Communications Engineering Test Satellite (OICETS)

OICETS will be launched into low Earth orbit carried by the J-1 launch vehicle in the middle of 2000 to conduct on-orbit demonstrations of pointing, acquiring, and tracking technologies and other key technological elements for optical communications. The on-orbit demonstrations will be conducted by using the ARTEMIS, a geostationary satellite of ESA.

3. Data Relay Test Satellite (DRTS)

DRTS system is composed of two geostationary satellites (DRTS-W and DRTS-E). They are scheduled to be launched by H-II A launch vehicles in 2000 (DRTS-W) and 2001 (DRTS-E). In this programme, technologies in two fields are to be developed and tested in space; the advanced data relay technologies for inter-orbit communication, and the technological basis necessary for middle class three-axis geostationary satellite buses.

F. Earth observation

1. Advanced Earth Observation Satellite (ADEOS)

The National Space Development Agency of Japan (NASDA) launched ADEOS by the H-II launch vehicle on 17 August 1996. The main objectives of ADEOS were:

- To develop advanced Earth observation sensors;
- To develop a modular satellite that will be the key technology of the future platform;
- To contribute to domestic and international cooperation by carrying announcement-of-opportunity (AO) sensors developed by domestic and foreign organizations;
- To acquire data on worldwide environmental changes in order to contribute to international global environmental monitoring.

ADEOS carried two core sensors, Ocean Color and Temperature Scanner (OCTS), and Advanced Visible and Near Infrared Radiometer (AVNIR), as well as other six AO sensors. Data gained by those sensors were expected to elucidate the mechanism of global environmental changes.

But because of the malfunction of the on-board electrical power supply, NASDA decided to abandon the operation on 30 June 1997.

2. Tropical Rainfall Measuring Mission (TRMM)

TRMM is being jointly conducted by Japan and the United States to measure tropical rainfall. Over two thirds of total rainfall, one of the main sources of global climate change on the Earth, occurs in tropical areas. TRMM will be the first mission carrying a precipitation radar to monitor tropical rainfall from space. TRMM will be launched in 1997 by the H-II launch vehicle.

3. Advanced Earth Observation Satellite II (ADEOS-II)

ADEOS-II, a successor to ADEOS, will be launched by the H-II launch vehicle in 1999. The objectives of ADEOS-II are to observe global environmental change, to contribute to international science programmes such as the International Geosphere-Biosphere Programme, and to follow the ADEOS mission. The satellite is a modular type with a flexible solar array paddle. ADEOS-II will have two core sensors developed by NASDA, namely an advanced microwave scanning radiometer (AMSR) and a global imager (GLI).

G. Development of engineering test satellites (ETS)

The objective of the ETS programme is to develop the high-level technologies required for the practical utilization of satellites.

Engineering Test Satellite VII (ETS-VII)

ETS-VII is to be dual-launched with TRMM from the Tanegashima Space Center. The purpose of ETS-VII is to acquire the basic technologies of rendezvous-docking and space robotics that are essential to future space activities. ETS-VII consists of a chaser satellite and a target satellite.

H. Space transportation system

1. Launch vehicles in the H-II series

NASDA is planning to upgrade the H-II launch vehicle for the purpose of responding flexibly to a variety of future launching needs. Based on the H-II launch vehicle, the advanced H-II launch vehicle (H-IIA) will meet various needs through reconfiguration of boosters considering the types and number.

2. Launch vehicles in the M or Mu series

ISAS has started to develop the M-V launch vehicle to provide larger launch capability to meet the requirements of space science in the late 1990s and the twenty-first century. M-V will be 2.5 metres in diameter and 30 metres in length, and will weigh 35 tonnes. It will be able to launch a payload of 1,800 kilograms into the low Earth orbit or 400 kilograms beyond the Earth gravitation region. The first M-V flight is scheduled in 1997. Six spacecraft, MUSES-B for the space VLBI (1997), Lunar-A for the Moon Penetrator Mission (1997), and PLANET-B for the Mars Orbiter (1998), ASTRO-E for X-ray astronomy (1999) and MUSES-C for asteroid sample return (2001), and ASTRO-F for infrared astronomy (2002) have already been approved for launching by M-V.

The use of M-V launch vehicles is being discussed for the pursuit of a variety of space science projects and fields of study in the near future, including the following: the Comet Coma Sample Return Mission, the Lunar/Mars Rover, the Venus Aerocapture/Balloon Mission, infrared astronomy, solar physics and atmospheric science.

I. Space experiments and utilization of the space environment

1. JEM development

Japan participates in the International Space Station Programme by developing the Japanese Experiment Module (JEM). JEM is composed of four main parts: the Pressurized Module, Exposed Facility, Experiment Logistics Module, and Manipulator.

The element level test of Engineering Model (EM) will finish in September 1997. Then, the JEM overall EM test will be performed by March 1998, and the development of Flight Model will progress as scheduled. JEM will be launched separately by the Space Shuttle from May 2001 and will then be assembled in orbit.

2. Manipulator Flight Demonstration (MFD)

The Manipulator Flight Demonstration (MFD) is to demonstrate the functions and performances of the Robot Arm similar to the JEM Remote Manipulator System (JEMRMS) Small Fine Arm using the Space Shuttle prior to a JEM launch. The MFD was conducted on STS-85 in August 1997.

The Robot Arm was installed in the Shuttle Orbiter Cargo Bay and operated by crews in the Aft Flight Deck of the Shuttle Orbiter using hand controllers. Also, the advanced experiment of Robot Arm controlled from the ground was conducted.

3. Space Radiation Environment Measurement Programme

NASDA participated in the fourth and sixth Shuttle/MIR Missions, in September 1996 and May 1997, as the contribution to the ISS Phase I Program, by proving RRMD (Real-time Radiation Monitoring Device), to measure and assess cosmic radiation inside the pressurized space vehicle on the ISS orbit.

4. First Microgravity Science Laboratory (MSL-1)

NASDA participated in the First Microgravity Science Laboratory (MSL-1), which was conducted on STS-83 in April 1997 and STS-94 in July 1997, and conducted material experiments with the Large Isothermal Furnace (LIF).

5. Space Experiments on board MIR

NASDA conducted two space experiments using the Russian space station MIR in 1997.

J. Basic and pioneering space technology research

1. Hypersonic Flight Experiment (HYFLEX)

HYFLEX is one of the flight experiment series in the HOPE-X project. The purposes of HYFLEX were to accumulate data on design and production technology, as well as flight technology and flight data of craft flying at hypersonic speeds. It was launched by the J-I launch vehicle and separated at an altitude of 110 km in February 1996. Unfortunately, the rope was torn off and the body sank into the sea, but the experimental data were found to match well the estimation.

2. Automatic Landing Flight Experiment (ALFLEX)

The purpose of the ALFLEX project was to develop design and production technology for a craft during low-altitude flights and landing operations. It also intended to establish technology for automatic landings. All test flights were carried out successfully from July to August 1996 at Woomera Airfield, Australia. The flight body was released from a helicopter at high altitude and automatically landed at the test site after gliding through the air. Collected data is used to establish the basic technology for the fully unmanned automatic landing.

3. HOPE-X

HOPE-X will be developed to perform flight experiments as a part of a reusable-type transportation system, which can reduce transportation costs drastically. HOPE-X will establish major technologies for an unmanned winged space plane and enable Japan to accumulate technology for a future study of reusable transportation systems.

MALAYSIA

[Original: English]

A. Commercial telecommunications satellites

Malaysia launched its first commercial satellite MEASAT-1 on 13 January 1996 and the second MEASAT-2 on 14 November 1996. Both satellites are privately owned by Binariang Sdn. Bhd and were manufactured by Hughes and launched by Arianespace.

B. Experimental satellites

In 1996, Malaysia entered formal negotiations with Surrey Satellite Technology Limited (United Kingdom) for the procurement of a 50 kg microsatellite with payloads for Earth observation, store-and-forward communications and cosmic ray experiments.

C. Ground receiving stations

The technical specifications for an Earth observation receiving station were successfully instituted and a request for proposals was sent out to several international companies.

D. International cooperation

Malaysia actively participates in the ESCAP-led Regional Space Application Programme for Development (RESAP). Malaysia also continues its strategic links with Argentina, Brazil, France, India, Indonesia, Thailand, United Kingdom and United States in various aspects of its activities.

SWEDEN

[Original: English]

A. National organization of space activities

1. The Swedish National Space Board (SNSB)

The Swedish National Space Board, established in 1972 under the Ministry of Industry and Trade, is the central governmental agency responsible for the Swedish national and international space and remote sensing programmes, particularly for R & D. For the basic research programme the Board receives funds from the Ministry of Education and Science.

The responsibilities of the SNSB include:

- Initiating research, development and other activities connected with the Swedish space and remote sensing programme;
- Coordination of Swedish activities within the fields of space technology and research as well as remote sensing;
- Distribution of government appropriations for Swedish space activities;
- Authorization and supervision of space activities in accordance with space law;
- Maintaining contacts with international organizations and institutions operating within the field of space activities and remote sensing.

SNSB has three advisory committees: for industrial policy, science (including microgravity) and remote sensing, respectively.

The technical implementation of the national space and remote sensing programmes are mainly contracted by SNSB on an annual basis to the State-owned Swedish Space Corporation (SSC), which was also established in 1972.

2. The Swedish Space Corporation (SSC)

In addition to performing its tasks for SNSB, the Swedish Space Corporation is active in a number of areas related to space technology and remote sensing. It is organized in five divisions with the following main activities:

- Esrange Division: sounding rocket and balloon launchings, scientific satellite support;
- Earth Observation Division: satellite TT&C services, data acquisition, archiving and processing of data from Earth observation satellites, production and marketing of satellite data and enhanced products;
- Science Systems Division: design and project management for space science research satellites, development of sounding rocket and balloon payloads, supply of microgravity services and satellite navigation systems;
- Telecom Division: television broadcasting, business television, data communication services and news gathering;

- Remote Sensing Technology Division: assistance to SNSB and other domestic and international government agencies, systems and methodology development within Earth observation, development and marketing of airborne systems for maritime surveillance and environmental control.

The Swedish Space Corporation has five establishments, three in Kiruna (Esrange, the subsidiaries SSC Satellitbild and the Environmental Satellite Data Centre-MDC) and two at Stockholm (headquarters and the subsidiary GP&C Sweden AB).

B. Space applications programmes

1. Remote sensing of Earth resources and environment

The main aim of SNSB's activities in this field is to promote the use of satellite and other remote sensed data for societal applications with priority for four areas: environmental monitoring, forestry, meteorology and topographic mapping.

The largest part of the activities are carried out in international cooperation. Sweden has a long-standing cooperation with France in the SPOT remote sensing satellite programme. Sweden also participates in the development of the Végétation instrument to be launched on board the SPOT 4 satellite.

Esrange in Kiruna is one of the two principal stations in the SPOT network and SSC Satellitbild in Kiruna is processing and distributing SPOT data in cooperation with the French company SPOT Image. SSC Satellitbild specializes in providing geometrically precision corrected and analysed data from SPOT and other satellites (such as JERS-1 and Landsat) for the world market.

Sweden cooperates with the Russian Federation on the Resurs-01 programme. Esrange is the only ground station outside the Russian Federation that receives Resurs-01 data and SSC Satellitbild is responsible for the world distribution of Resurs-01 data.

Sweden participates in the ESA Earthnet programme for receiving, preprocessing, archiving and distribution of images from remote sensing satellites. The Swedish ground station at Esrange forms part of the system and is collecting Landsat data on a routine basis.

Sweden also participates in the remote sensing programmes of ESA such as the programme for development of remote sensing satellites (Envisat-1/Polar Platform), the earth observation preparatory programme (EOPP) and the Earth Explorer/Earth Watch programmes. There is an agreement with ESA to receive and process ERS-1 and ERS-2 data. A separate ESA Satellite Station has been established for that purpose at Salmijärvi (near Esrange).

The Swedish Space Corporation, in cooperation with relevant public authorities, established in 1995 the Environmental Satellite Data Centre (MDC) in Kiruna. The primary tasks of the Centre will be production and management of environmental data sets for public authorities, researchers and international institutions. The aim is also to become a major node in the international network and a link between data suppliers and end-users.

In 1995 the Tromsö Satellite Station in Norway (receiving station for data from polar orbiting satellites) became a corporation jointly owned by the Norwegian Space Centre and the Swedish Space Corporation.

2. Meteorology

Cloud cover photographs and other meteorological data from ESA, United States and Russian weather satellites are received regularly by the High-Resolution Picture Transmission (HRPT) and Automatic Picture Transmission (APT) stations of the Swedish Weather Services and are used in weather forecasting.

A project concerning the establishment of short-term weather forecasting and regional weather service based on advanced space and remote sensing techniques, including weather radar, microwave radiometry and weather satellites, has entered into an operational phase.

Development of the operational use of advanced digital image analysis of polar weather satellite data is going on. A microwave radiometer for sounding of temperature and humidity of the atmosphere has been developed for operational use.

Sweden participates in the meteorology programmes of ESA and Eumetsat, such as the programmes for development of the geostationary satellites Meteosat Second Generation (MSG) and the preparatory programme for polar satellites Metop.

3. Communications

Sweden participates in the telecommunications programmes of ESA such as the programmes for Advanced Research in Telecommunications Systems (ARTES), the technology demonstration mission (ARTEMIS) and data relay satellites (DRS).

On a national level, the Swedish Space Corporation (Esrange) operates - under contract to the Nordic Satellite Company, NSAB - the Tele-X/Sirius telecommunications satellite system, which provides television and broadcasting services, data transmission etc.

4. Navigation

Satellite navigation equipment is in routine use on Swedish merchant vessels using Transit/Navstar-type satellites.

SSC holds the Swedish patent on GP&C (Global Positioning and Communication), a system which enables many mobile units to exchange position data and other information using a single radio channel. The following functions are offered by the GP&C system: navigation, identification, surveillance, situation awareness, communication.

Sweden participates in the ESA programme element (ARTES 9), which is part of a cooperation project between ESA, Eurocontrol and the European Commission aiming at a European contribution to a Global Navigation Satellite System.

5. Space transportation

Sweden participates in the ESA programmes for development of the Ariane launchers, i.e. the Ariane 5, as well as in the programmes aimed at improving the launcher and future transportation systems. The main Swedish industries involved here are Volvo Aero Corporation (combustion chambers and nozzles) and Saab Ericsson Space (on-board computers, separation systems and telemetry antennas). Development work in the areas of specific Swedish interest is prepared in bilateral cooperation with France.

C. Scientific space programmes

1. Satellites

Viking, Sweden's first satellite was launched from Kourou in February 1986. The mission ended in May 1987. The scientific objective of the Viking satellite was to study the ionospheric and magnetospheric phenomena at high geomagnetic latitudes in the attitude region up to about two Earth radii.

Freja, Sweden's second one, was also a scientific satellite (214 kg) designed to carry instruments for research into the aurora and other magnetospheric/ionospheric phenomena. The low-cost designed satellite was launched on 6 October 1992, on the Chinese carrier Long March 2. The project was carried out in cooperation with, *inter alia*, the Federal Republic of Germany. The scientific mission of Freja had many similarities with that of Viking. The auroral zone was the "mission target" and the satellite carried energetic particle detectors, magnetic and electric wave experiments, electric field sensors and a UV imager.

Astrid 1 is a Swedish microsatellite, launched in January 1995 from Plesetsk in the Russian Federation into a polar orbit. Astrid's main scientific mission was to investigate near-space plasma, particularly neutral particle phenomena. High resolution measurements in the upper ionosphere and the lower magnetosphere have contributed to increasing the knowledge of basic processes of fundamental importance to the physics of neutral particles. The payload was designed by the Swedish Institute for Space Physics in Kiruna.

Astrid-2, a second microsatellite (30 kg) for space plasma physics, is planned for launch in late 1997/early 1998. Astrid 2 carries a comprehensive plasma physics instrument package developed by institutes in Sweden (Dpt of Plasma Physics of the Alfvén Laboratory at the Royal Institute of Technology, Stockholm and the Swedish Institute of Space Physics in Uppsala), the United States and Germany.

Sweden's next small scientific satellite Odin (250 kg), with a combined astronomy and aeronomy mission, is under development. Odin is a scientific satellite for spectroscopic studies at submillimetre wavelength of astronomical objects and processes in the Earth's upper atmosphere. The project is carried out in cooperation with Canada, France and Finland. The launch, on a Russian launcher, is planned for 1998 with an operational lifetime of two years.

2. Sounding rockets and balloons

Swedish sounding rocket and balloon launches have been carried out since 1962 and since 1968 from Esrange, mostly as international cooperative projects.

The Swedish sounding rocket and balloon programme is concentrated on four main areas:

- Magnetosphere and ionosphere physics;
- Upper atmosphere physics and chemistry;
- Astrophysical infrared and submillimetre studies;
- Materials, fluid and bioscience in microgravity.

The Swedish Space Corporation is responsible for the technical execution of the projects as well as for the operation of Esrange.

The Swedish MASER programme (Materials Science Experiment Rockets) which started in 1987, offers one launch per year for experiments within materials physics, fluid science and bioscience.

There is an increasing interest in microgravity experiments of long duration. A programme, named MAXUS, is carried out jointly with Germany and it is based on a required payload weight of 750 kg and 14-15 minutes of microgravity.

3. Ground-based experiments

Sweden is participating in the work of the European Incoherent Scatter Scientific Association - EISCAT. The association has installed a multistatic incoherent scatter facility in the auroral zone, comprising a system of stations at Tromsö and Svalbard (Norway), Kiruna (Sweden) and Sodankylä (Finland).

4. Swedish space research

The Swedish scientific activities fall mainly within the following areas:

- Magnetospheric and ionospheric physics, in particular measurements of charged particles and electric and magnetic fields using satellite experiments, sounding rockets and balloons (Swedish Institute of Space Physics in Kiruna and Uppsala, Dept. of Plasma Physics of the Alfvén Laboratory, Royal Institute of Technology, Stockholm);
- Study of the upper atmosphere (80-150 km), in particular atmospheric processes and composition at high latitudes using sounding rockets (Inst. of Meteorology, Stockholm University);
- Astrophysics, in particular studies of solar and stellar UV radiation and IR and submillimetre studies using satellites, sounding rockets and balloons in international cooperation (Onsala Space Observatory and the Observatories of the Universities of Lund, Stockholm and Uppsala);
- Materials sciences, in particular solidification processes of metals, diffusion processes in liquid metals and crystal growth in microgravity using sounding rockets (Dept. of Casting of Metals, The Royal Institute of Technology, Stockholm and the University of Sundsvall);
- Life sciences, in particular studies of human physiological processes in microgravity (Environmental Physiology Laboratory at the Karolinska Institutet, Stockholm);
- Biophysics, in particular electrophoretic and protein crystal growth studies in microgravity (Dept. of Physical and Inorganic Chemistry, Chalmers University of Technology, Gothenburg);
- Remote sensing, in particular microwave radiometry, spectral signatures and image analysis using satellite data or data registered by airborne or land-based sensors (Dept. of Radio and Space Science at Chalmers University of Technology in Gothenburg; Remote Sensing Laboratory, Dept. of Physical Geography of the Universities of Stockholm and Lund respectively; Dept. of Physics at the Lund Institute of Technology and the Remote Sensing Laboratory at the Swedish University of Agricultural Sciences in Umeå).

D. Esrange

Esrange is a Swedish space research and space operations range situated in northern Sweden, close to the town of Kiruna at a latitude of about 68° North. The base is managed by the Swedish Space Corporation.

Space research activities are carried out at Esrange in international cooperation using ground-based instrumentation, sounding rockets, balloons and satellites. Due to the geographical location, studies of the aurora and other high-latitude phenomena are of particular interest.

The land recovery possibility makes Esrange very suitable for all sounding rocket experiments needing recovery, for instance microgravity research. Esrange has the capacity to launch most types of sounding rockets. The range also has long experience of launching scientific balloons. The Esrange sounding rocket and balloon activities are performed as an ESA Special Project. Contributing ESA members can use the range on a marginal cost basis. Also non-ESA members are welcome to use the facilities.

Esrange is also used in various satellite projects. A number of ground facilities for the support of national and international spacecraft programmes are in operation or under development. The majority of the passages of polar orbiting satellites are inside the coverage zone of the Esrange satellite ground stations. A Tracking, Telemetry and Control (TT&C) station is used to support polar satellites during the launch phase and when in service in their nominal orbits. The station includes a dedicated Operations Centre and a display and analysis facility for scientific data.

E. Other space-related facilities and installations including telemetry and acquisition

The Onsala Space Observatory, located on the Swedish west coast, operates radiotelescopes, mainly for radioastronomical observation. The newest telescope has a radome-enclosed 20 m diameter reflector with very high surface accuracy for work at millimetre wavelengths.

A joint Scandinavian Intelsat Earth station is located at Tanum on the west coast of Sweden. A joint Scandinavian Earth station for the European Communication Satellite System (ECS) is located near Stockholm. Several HRPT and APT weather picture receiving stations are in operation.

F. International cooperation

Most of Sweden's international cooperation is performed within the framework of ESA. In addition to the mandatory basic and scientific programmes, Sweden participates in the Ariane launcher programme as well as in the projects for future space transportation systems, the programmes for manned space, telecommunications, remote sensing and microgravity. Sweden is also a member of INTELSAT, EUTELSAT, Inmarsat and EUMETSAT.

Bilateral scientific cooperation between Sweden and the United States is carried out under an agreement with NASA. Bilateral cooperation on space science and applications (SPOT) is carried out between Sweden and France under agreements with Centre National d'Etudes Spatiales (CNES). Memoranda of Understanding have been concluded as basis for cooperation with Austria, Canada, India and China. Other bilateral cooperative efforts are carried out on an ad hoc basis.

G. Other activities

1. Courses

Sweden has a broad experience of remote sensing and Geographical Information Systems (GIS) at governmental agencies, universities and companies. This experience and know-how can be made available to developing countries where there is need for mapping and other forms of remote sensing applications. There is thus an increasing demand for technology transfer in the form of training of personnel from developing countries.

For this purpose, a Swedish Institute for Geographical Information Technology (SIGIT) has been established in Kiruna. The institute offers courses in practical application of remote sensing. The courses are based on the resources of, *inter alia*, university institutes, the SSC Satellitbild company and the Swedish Land Survey in the area. The aim is to meet high vocational demands of both national as well as international students and trainees in the field of remote sensing and geographic information technology.

Annual United Nations Training Courses on Remote Sensing Education for Educators started in Sweden in 1990 and are hosted by the Swedish Government. The courses are carried out jointly by the University in Stockholm (Dept. of Physical Geography) and the SSC Satellitbild in Kiruna.

SWITZERLAND

[Original: English]

A. National space policy

The national space policy is determined by the Federal Council (Government) under the advice of a 20-member Federal Space Affairs Commission (CFAS). The Committee on Space Research of the Swiss Academy of Sciences coordinates and stimulates space research in Switzerland.

Guidelines

The Swiss space policy follows four main guidelines:

- Switzerland must use the possibilities offered by space activities in the interest of international collaboration and to improve the way of life on our planet: Swiss space policy means Swiss foreign policy;
- Switzerland must concentrate its space activities on ESA - also in the future: Swiss space policy means Swiss policy on Europe;
- Science, research and application are of primordial importance in this sector, and therefore, the education of scientists and researchers must be fostered and promoted: Swiss space policy means Swiss science policy;
- A technologically advanced industrial tissue is of undeniable importance to preserve the prosperity of people: Swiss space policy means stimulation of Swiss high technology.

B. Current space activities

Space research in Switzerland is performed individually by various laboratories of the universities, the Federal Institute of Technology and Industry Laboratories. The research is supported by the Swiss National Science Foundation as well as by the Cantonal and Federal Governments.

No national programme being pursued, Swiss space involvement is almost totally routed through ESA. Out of the annual Swiss ESA contribution:

- More than 50 per cent are directed to the mandatory science programme, to Earth observation, microgravity and PRODEX ("programme de développement d'experiences scientifiques") programmes in which Switzerland contributes systematically at GNP level (4 per cent). These scientific missions give Swiss scientists the opportunity, when selected, to fly on ESA missions, experiments whose development are mainly funded through the ESA PRODEX programme;
- 17 per cent are directed to launchers and the Guyana Space Center;
- 12 per cent to manned space programmes;
- 9 per cent to technology, telecommunication and navigation programmes.

C. Main aims

1. Space science

- Support a strong ESA science programme and secure a leading role for Europe in several areas of space science;
- Support through the PRODEX programme the development of experiments on ESA missions;
- Support the ESA Integral Science Data Center near Geneva;
- Support the Berne-based International Space Science Institute co-funded by Switzerland and ESA.

2. Earth observation

- Support a strong ESA earth observation programme;
- Foster worldwide collaboration between space users by supporting Swiss centres of competence at university level nationally and promoting their applications for participation in ESA Earth observation projects;
- Promote the use of space-borne Earth observation data and foster technology transfer into the private sector via ESA's Data User Programme;
- Support the Swiss Scientific Computing Center in Manno as a node in the planned European network on Earth observation (CEO).

3. Microgravity

- Exploit and sustain new Swiss scientific teams which have recently demonstrated their capabilities in biomechanics and human physiology;
- Support early flight opportunities;
- Maximize the reuse of existing industrial capabilities;
- Maintain the existing activities in cell biology;
- Try to build up a community of material and fluid physicists interested in space experiments.

4. PRODEX

Swiss policy for ESA's PRODEX programme is:

- Implement a coherent science policy under the guidance of the PRODEX Programme Committee of the Federal Space Affairs Commission;
- Promote the synergy between Swiss industries and institutes.

Before 1986, the financing of the scientific experiments on-board ESA missions was entirely the responsibility of the university institutes and the Swiss National Science Foundation. Because their subsidiaries have been limited in both duration and scope, it has happened more than once that an accepted Swiss project has subsequently had to be withdrawn because its funding could not be ensured.

In 1986, the PRODEX programme, a promotional tool reserved solely for missions organized or co-funded by ESA, allowed us to solve widely this problem. Thanks to the success of the PRODEX programme, Switzerland has been able to finance or co-finance nine experiments for the ESA science programme.

Project	*Flight*	*Institute*
CELIAS Energy Analyser of Mass Spectrometer	SOHO 1995	Berne University
VIRGO Variability of Irradiance and Gravity Oscillation	SOHO 1995	Physikalisch-meteorologisches Observatorium Davos World Radiation Center
UVCS Participation in UVCS/CDS and SUMER Measurements of the UV Radiation of the Solar Corona	SOHO 1995	Federal Institute of Technology, Zurich

Project	*Flight*	*Institute*
SOHO calibrations In-orbit calibration of SOHO CDS/SUMER/UVCS	SOHO 1995	Federal Institute of Technology, Zurich
RGS Reflexion Grating Spectrometer	XMM, 1999	Paul-Scherrer Institute & Geneva Observatory
SWICS ESA Archives on the Solar Wind Composition Spectrometer	Ulysses, 1990	Berne University
IREM Integral Radiation Environment Monitor	Integral, 2001	Paul-Scherrer Institute
ROSINA Rosetta Orbiter Spectrometer for Ion and Neutral Analysis	Rosetta, 2003	Berne University
HMASER Hydrogen Maser for Radioastron	Radioastron, ?	Neuchâtel Observatory

5. Small satellites

- Exploit the instrumental capabilities developed in the PRODEX programme;
- Seek early involvement in the small satellites projects of ESA (SMART, EUROMOON etc.);
- Develop small terminals for optical intersatellite links in cooperation with scientific institutes and international partners;
- Encourage the development of relations between design expertise and operational entities.

6. Navigation

- Take part in Europe's Global Navigation by Satellite (GNSS) programme through ESA and EUROCONTROL;
- Encourage the coordination of activities with the European Union;
- Encourage the setting up of a European institution for regulating global satellite navigation;
- Support the installation of a Ranging Integrity Monitoring Station in Switzerland;
- Develop new generation atomic clocks suited for second generation GNSS.

7. Launchers

- Contribute to develop effective and competitive international launch services through Switzerland's involvement in the Ariane-5 programmes;
- Encourage the opening of governmental launch market worldwide;
- Contribute to the Europeanization of the Guyana Space Center by supporting the installation of Swiss companies in Guyana;
- Support the pre-development of key technologies (structure, materials, propulsion) for the next generation of launchers in view of significant reduction in launch costs.

8. Manned space activities

- Become a signatory of the Intergovernmental Agreement on the International Space Station (ISS);
- Confirm a leading role for Swiss industry in the Automated Transfer Vehicle;
- Help strengthen the operational role of the European Robot Arm;
- Promote the utilization of the ISS by the Swiss scientific community;
- Use the ISS as a laboratory for space science, Earth observation and microgravity research activities in an easy and quick way involving as little bureaucracy as possible;
- Support regular flight opportunities.

9. Technology

- Implement a coherent technology policy under the guidance of the Technology Policy Committee of the Federal Space Affairs Commission;
- Fully exploit the technological potential existing in universities and technical institutes (i.e. micro-nano technologies, opto-electronics etc.);
- Encourage and support the creation of spin-offs in space and non-space markets;
- Foster the competitiveness of Swiss equipment suppliers on the world market.

UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

[Original: English]

The annual report of the United Kingdom is contained in the brochure entitled United Kingdom space activities 1996-1997, distributed to the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space at its thirty-fifth session.

UNITED STATES OF AMERICA

[Original: English]

A publication entitled "Aeronautics and Space Report of the President: Fiscal Year 1996 Activities" will be distributed to the Scientific and Technical Subcommittee at its thirty-fifth session.

UNITED
NATIONS

A

General Assembly

Distr.
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A/AC.105/680
1 December 1997

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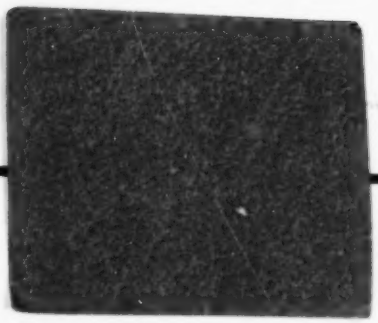
COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE



NATIONAL RESEARCH ON SPACE DEBRIS

SAFETY OF NUCLEAR-POWERED SATELLITES

PROBLEMS OF COLLISIONS OF NUCLEAR-POWERED SOURCES WITH SPACE DEBRIS

Note by the Secretariat

CONTENTS

	Paragraphs	*Page*
INTRODUCTION	1-4	2
REPLIES RECEIVED FROM MEMBER STATES		3
Canada		3
Chile		3
France		3
Indonesia		4
Japan		7
Sweden		11
United Kingdom of Great Britain and Northern Ireland		11
REPLIES RECEIVED FROM INTERNATIONAL ORGANIZATIONS		18
International Law Association		18
International Telecommunications Satellite Organization (INTELSAT)		18

Figures

I.	Development Scheme of the Indonesian Orbital Debries Monitoring System	4
II.	Echo distribution on longitude versus latitude plane	6
III.	Number of meteor echoes as a fraction of time	6

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INTRODUCTION

1. In its resolution 51/123, paragraph 32, of 13 December 1996, the General Assembly considered it essential that Member States pay more attention to the problem of collisions of space objects, including nuclear power sources, with space debris, and other aspects of space debris, and called for the continuation of national research on that question, for the development of improved technology for the monitoring of space debris and for the compilation and dissemination of data on space debris. To the extent possible, the Assembly considered that information thereon should be provided to the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space.

2. The General Assembly, in paragraph 22 of the same resolution, invited Member States to report to the Secretary-General on a regular basis with regard to national and international research concerning the safety of nuclear-powered satellites.

3. The Secretary-General addressed a note verbale dated 7 August 1997 to all Member States, inviting them to communicate to the Secretariat, by 30 September 1997, the information requested above so that the Secretariat could prepare a report containing that information for submission to the Subcommittee at its thirty-fourth session.

4. The present document was prepared by the Secretariat on the basis of information received from Member States and international organizations as of 30 November 1997. Information received subsequent to that date will be included in addenda to the present document.

REPLIES RECEIVED FROM MEMBER STATES*

Canada

[Original: English]

With regard to nuclear power sources and space debris issues, the Government of Canada is referring to the information provided last year and available in document A/AC.105/659.

Chile

[Original: Spanish]

Chile does not possess spacecraft that utilize nuclear power sources and has not considered the use of such technology in the future. In that connection, it is appropriate to mention the experience with the fall of the Russian probe Mars 96 into the Pacific Ocean as regards the investigation and the search carried out for debris and for evidence of radioactive contamination.

With regard to the minimization of space debris, the experience of the *Fuerza Aérea de Chile* with mini-satellites of the FASat series is in accordance with the application of the practices adopted by the United Kingdom company Surrey Satellite Technology Limited, as follows:

- Securing to the structure, whether of the launch vehicle or of the satellite itself, all the components or parts that might lose their original fastenings during the process of placing in orbit, including the remains of components subject to breakage.

- Use of materials suitable for space in that they do not suffer damage as a result of outgassing or of other environmental conditions that might result in the creation of debris, including the surface treatment of the materials concerned.

- Ensuring that all the structural fastenings and all the parts of the satellite as a whole are capable of withstanding the mechanical conditions of the launch, placing in orbit and subsequent operation, and of maintaining the integrity of the structure.

France

[Original: French]

The text of the French contribution has been incorporated into the document on space debris mitigation techniques (A/AC.105/681).

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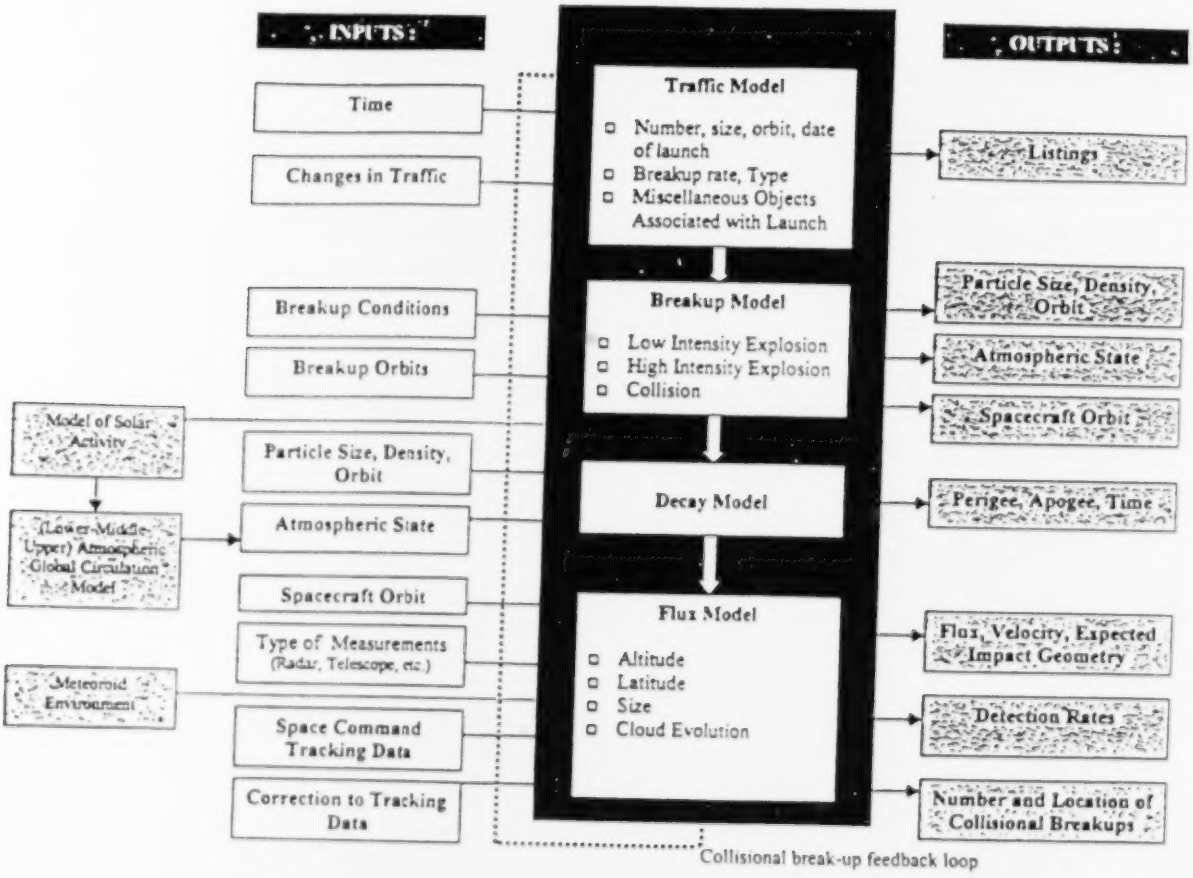
*The replies are reproduced in the form in which they were received.

Indonesia

[Original: English]

The Government of the Republic of Indonesia pays great attention to the problem of space debris and its related aspects. In facing this problem Indonesia is now developing an Indonesian Orbital Debris Monitoring System (IODMS) which includes four main models: Traffic Model (TM), Break-up Model (BM), Decay Model (DM) and Flux Model (FM). The IODMS is a dedicated monitoring model for man-made space debris, but it takes into account the natural space debris information (figure I).

Figure I. Development scheme of the Indonesian Orbital Debris Monitoring System



The Indonesian Orbital Debris Monitoring System is now under development. The final four outputs of the system will become the main inputs for the space debris mitigation action programmes as well as for the national space policy including policy on impacts of space debris.

It was inescapable that orbital debris would become an environmental issue requiring models and measurements to understand this new environment. The models and measurements developed are identical in many respects to the models and measurements used to understand the interplanetary meteoroid environment.

Both the meteoroid and orbital debris investigators can, and have, benefited by sharing data and modelling techniques.

The IODMS will generate information on orbital debris as follows:

- Traffic list
- Particle size, density, orbit
- Atmospheric state
- Spacecraft orbit
- Perigee, apogee and time
- Flux, velocity, expected impact geometry
- Detection rates
- Number and location of collisional break-ups.

Based on the above generated information, action programmes (both prevention and mitigation) on space debris and its related aspects could be developed.

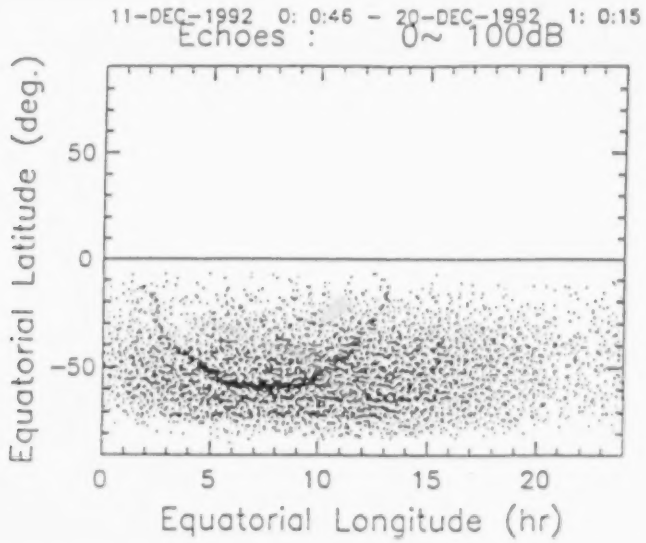
The IODMS development status is still a basic concept with a number of limited capabilities of software, hardware and human resources. Specifically, the said capabilities include among others: Solar Activity Model and Atmospheric Global Circulation Model, Meteoroid Environment Model, measurement instruments (e.g. Meteor Wind Radar, MF Radar, Wind Profiling Radar, Bounder Layer Radar, optical telescopes) and a number of scientists who have experience in developing models. Output of the above models and observational data acquired by using the instruments will become inputs for the IODMS. Indonesian specialists will develop the necessary models by either integrating the existing technology or developing their own. At this time Indonesia has the necessary knowledge and expertise on the development of FM, DM and TM, but is still limited for developing BM, especially on the intensity of explosions including both the low and the high intensity explosions.

Models have predicted that the orbital debris environment could exceed the meteoroid environment in certain regions of low Earth orbit. Observations have confirmed this prediction, and have shown that the effects are dependent on the pointing direction and size regime. The observations are also revealing sources of debris that were not predicted.

Based on the existing observations in Indonesia, there was indication that from 11 to 20 December 1992, "space debris rains" occurred above the southern hemisphere in the region of Indonesia (figure II). These indications were also shown by the number of meteor echoes in 1992 and 1993 (figure III). A number of detected spikes are not associated with any known meteor showers. The most likely explanation for the pattern of those spikes, based on the echo distributions on longitude versus latitude plane (figures II and III) is man-made debris. Unfortunately, there is no information on launching activities during these periods. Further investigations involving the orbital monitoring system are required to confirm this conclusion.

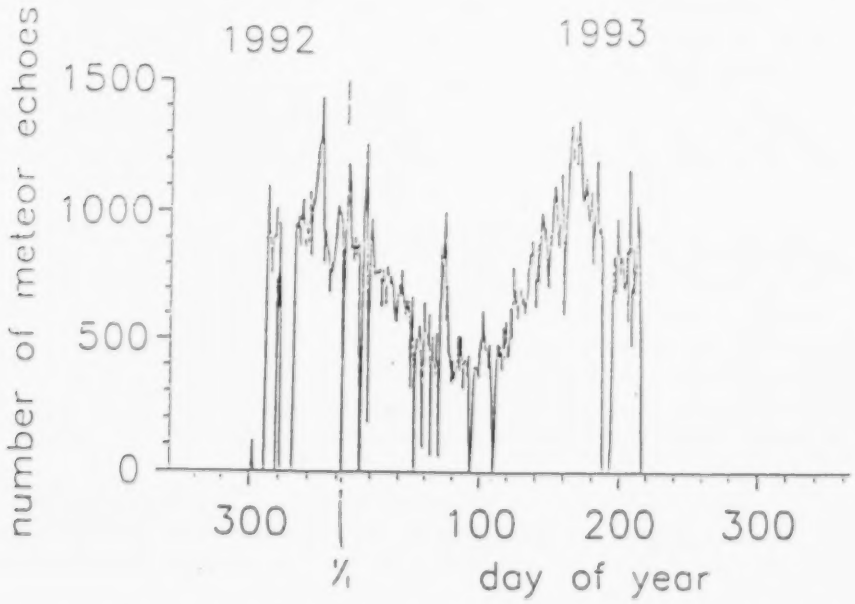
An ever-increasing measurement programme is essential towards understanding and controlling the growth in the future orbital debris environment. For the purpose of developing the above scheme (the IODMS), the Government of the Republic of Indonesia invites cooperation and/or exchange of data/information for mitigating the orbital debris as well as their negative impacts.

Figure II: Echo distribution on longitude versus latitude plane



Two straight line echo distributions around latitude -65° and -70° are suspected to have originated from man-made space debris.

Figure III. Number of meteor echoes as a fraction of time



Number of meteor echoes as a fraction of time, observed with the Meteor Wind Radar, at Serpong, Indonesia. A number of detected spikes are not associated with any known meteor showers.

Japan

[Original: English]

A. Introduction

The Space Activities Commission of Japan (SAC) mentioned Japan's policy on space debris in the report on Japan's Space Long Term Vision published in July 1994 as follows: "Japan will aim to develop such systems that will leave as little space debris as possible."[1] Based on this policy, SAC revised the Fundamental Policy of Japan's Space Activities on 24 January 1996.[2] It contains the first Japanese policy statement on the preservation of the space environment.

The National Space Development Agency of Japan (NASDA) became aware of the risk of collision with debris and began to study it from 1985. The most comprehensive research was conducted from 1991 to 1993 in cooperation with the Japan Society for Aeronautical and Space Sciences (JSASS).

Systematic and organized activities have been performed since 1990 when the JSASS founded the Space Debris Study Group.[3] The Study Group of over 30 members from space-related organizations and industries issued an interim report in January 1992 and a final report in March 1993. Some recommendations in the reports have been continuously studied by two newly formed JSASS Study Groups.

Japan (NAL, NASDA, ISAS, and other space-related organizations) has also been a member of the Inter-Agency Space Debris Coordination Committee (IADC) since 1992 and has studied debris through exchange of information and discussion at the IADC, IAF, COSPAR and other international and domestic conferences.

This report is a brief overview of recent activities in Japan concerning measurement, database, mitigation of and protection from debris.

B. Measurement and detection

1. SFU post flight analysis

The JSASS, National Aerospace Laboratory (NAL) and other organizations are jointly performing the post-flight analysis of the Space Flyer Unit (SFU). SFU is an unmanned, reusable, sun-pointing, three-axis stabilized satellite. It is the first satellite of the kind built in Japan. It is octagonal in shape, measures 4.46 m in diameter and 3 m in height, and weighs about 4 tonnes. SFU was launched by the third H-II flight, on 18 March 1995, and was retrieved by the Space Shuttle STS-72 on 13 January 1996. SFU was operated on a circular orbit at an altitude of 500 km and inclination of 28.5 degrees. Preliminary results in impact surveys are summarized as follows:[4, 5]

- 337 impacts with diameters greater than 200 m have been observed in visual surveys
- 180 impacts with diameters greater than 200 m have been observed in high-resolution surveys of some surfaces
- The largest impact is located on the infrared telescope Multi-Layer Insulation (MLI), with perforation of diameter of 4.5 mm.

NAL continues detailed surveys and all the data will be made available to the public and archived in accordance with IADC rules. The database is available through the NAL Web site (http://www.nal.go.jp) and is constantly being updated.[6]

2. MFD evaluation of space environment and effects on materials (ESEM)

A flight demonstration test for the first Japanese robot arm of the Japanese Experiment Module (JEM), known as the Manipulator Flight Demonstration (MFD), was conducted on Space Shuttle flight STS-85 in August 1997. NASDA has performed the ESEM experiment of MFD in cooperation with NASA's Langley Research Center. A cosmic dust collector, mounted on top of the MFD experimental apparatus in the Shuttle payload bay, was exposed in space in the Shuttle flight direction for approximately 50 hours. A post-flight analysis is being conducted now.

3. System study on the on-orbit debris observation satellite

Since September 1996, JSASS has studied an optical measurement system for an on-orbit debris observation satellite in cooperation with NASDA. The purpose of the study is to define requirements of a small satellite system to determine the orbits of small debris near the geostationary orbit. The report includes the following contents:[7]

- Design of the orbit suitable for a debris observation satellite
- Method to improve accuracy of observations
- Detailed optical design for observations
- Study on a Breadboard Model (BBM) specification for on-board data-processing system
- Study on a BBM specification for ground data-processing system
- Study on a BBM specification for an observation satellite.

C. Modelling and database

NASDA has taken steps to develop a space debris database system named Space Debris Orbit Analysis Test System (DOANATS). DOANATS consists of two subsystems. One is the database subsystem that accumulates orbital data of space objects, and the other is the subsystem that analyses these orbital data.

The database subsystem acquires the orbital data from the United States Two Line Element Data from the Remote Bulletin Board System (RBBS) of the Goddard Space Flight Center. The re-entry time of each object is computed by the orbit analysis subsystem and registered in the database subsystem.

The orbit analysis subsystem contains the following four functions to determine the hazard of each space debris.

- Re-entry prediction function to estimate each space debris' re-entry time into the Earth atmosphere
- Collision analysis function to detect space debris that has high risk to collide with certain space systems
- Debris dispersion simulator to simulate orbital behaviour of the fragments generated by explosion or collision of space objects
- Orbit analysis function to provide some tools that are useful for analysis of the orbital data to space debris researchers.

D. Protection

NASDA has conducted a series of impact tests, by using a two-stage hydrogen light-gas gun, to design the JEM Stuffed Whipple bumper and a carbon-fibre reinforced plastic tube for the arm of the JEM Remote Manipulator System.[8]

NAL has conducted shaped-charge tests in collaboration with Mitsubishi Heavy Industries (MHI) and Chugoku Chemicals. The charge is 7.0 cm in diameter and 14.7 cm in length. The liner angle is 30 degrees. The thickness of aluminium liner is 2.1 mm. The copper inhibitor, which has a hole diameter of 15 mm, was selected through intensive parametric studies of inhibitor and reactive plate methods. A single cylindrical jet without a trailing jet was obtained by using this inhibitor. The mass of the tip jet is approximately 1.9 g, and the velocity obtained is approximately 10.6 km/s.[9] Comparisons between numerical results and experimental ones were presented at the Second European Conference on Space Debris.[10] NAL and MHI are planning to refine the inhibited shaped charge for JEM impact tests.

E. Mitigation

1. Standard

NASDA began to study to establish the Space Debris Mitigation Standard in 1993. The study was conducted in coordination with the orbital debris research project at NASA Johnson Space Center (JSC) to define guidelines and to establish criteria that would make NASA programmes compatible with the guidelines.

The draft of NASDA Debris Mitigation Standard was repeatedly presented at IADC to coordinate with other organizations, which was also reviewed by JSASS[11] and NASDA. Finally NASDA has established "the NASDA Space Debris Mitigation Standard" (NASDA-STD-18) on 28 March 1996.[12] Details of the NASDA Standard were presented at the thirty-fourth session of the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space.[13] Prior to the establishment of the NASDA standard, NASA established NASA Safety Standard 1740.14 "Guidelines and Assessment Procedures to Limit Orbital Debris Generation". A comparison between the NASA and the NASDA standards was shown at the 20th International Symposium on Space Technology and Science held in Gifu, Japan, from 19 to 20 May 1996,[14] which showed that these two standards had the same fundamental principles, although the NASA standard was scientifically oriented and the NASDA standard was rather engineering-oriented.

"NASDA Space Debris Mitigation Standards" requests mitigation measures to limit the orbital debris generated during launch, on-orbit operation, and after the mission of space objects.

The standard is based on the following concepts:

- The worst cause of deterioration of the orbital environment is on-orbit break-up of space objects caused by collision with a large object, accidental explosion and intentional destruction
- Preservation of the environment of the Geostationary Orbit (GEO) is particularly important because natural forces cannot clean up the debris in GEO
- Preservation of the environment of Low Earth Orbit (LEO) is also important because of its usefulness for various missions such as Earth observation and satellite communication.

From the above concepts, the Standard includes the following mitigation measures:

- Passivation of spacecraft and upper stages after their mission
- Reorbiting of spacecraft from GEO to other orbit after their mission
- Relocation of space objects in Geostationary Transfer Orbit (GTO) to prevent collision with space objects in GEO
- Minimization of debris released during normal operations of spacecraft and space objects
- Disposal of spacecraft from LEO after their mission.

2. Implementation and practices

Before the establishment of NASDA-STD-18, NASDA had carefully considered the development of space systems in order to mitigate the generation of orbital debris.

The upper stages of H-I and H-II launch vehicles were designed not to generate operational debris and to prevent on-orbit break-ups caused by residual energy. They were also given the reboost function after separating their payloads, which was effective to avoid long-period interference in the useful orbit. GEO satellites were also designed and operated to conduct reorbit manoeuvre at the end of the mission to preserve the GEO environment.

F. Conclusion

For the purpose of protecting the space environment, Japan will develop advanced R & D activities focusing on new fully-reusable transportation vehicles, based on a novel design concept obtained by the results of development of an advanced H-II launch vehicle and HOPE-X technologies.[1] It is needless to say that protection of space environment from space debris is necessary to ensure current and future human space activities. We need to take action now, while the space debris problem is still manageable and the costs of dealing with it are fairly low.

Notes

[1]"Toward creation of space age in the new century", Report on Japan's Space Long-Term Vision, Space Activities Commission, July 1994.

[2]Fundamental Policy of Japan's Space Activities, revised on 24 January 1996.

[3]S. Toda, "Some topics of space debris researches in Japan", 34th Session STSC UNCOPUOS, February 1997.

[4]M. J. Neish and others, "Micrometeoroid and space debris impacts on the space flyer unit and hypervelocity impact calibration of its materials", ESA SP-393, Proc. Second European Conference on Space Debris, May 1997, pp. 177-182.

[5]M. J. Neish and others, "Hypervelocity impact damage to space flyer unit multi-layer insulation", 7th Symposium of Materials in the Space Environment, 16-20 June 1997, Toulouse, France.

[6]S. Deshpande and others, "SFU micrometeoroid and space debris impact archive", 7th International Space Conference of Pacific-basin Societies, 15-18 July 1997, Nagasaki, Japan.

"Report on the detailed study on the precise optical measurement system for on-orbit debris observation system" (in Japanese), Japan Society for Aeronautical and Space Sciences, March 1997.

[8]K. Shiraki, F. Terada and M. Harada, "JEM Design Progress for the Micro-Meteoroid and Orbital Debris Protection", 96-m-21, 20th ISTS Gifu, Japan, 19-25 May 1996.

[9]M. Kobayashi and others, "Study of hypervelocity impact testing with shaped charge".

[10]M. Katayama and others, "Numerical study of jet formation by shaped charge and its penetration into bumpered target", ESA SP-393, Proc. Second European Conference on Space Debris, May 1997, pp. 411-416.

[11]R. Reynolds, A. Kato, J. Loftus and D. Kesseler, "Guidelines and assessment procedures to limit orbital debris generation", 96-m-15V, 20th ISTS Gifu, Japan, 19-25 May 1996.

[12]Space Debris Mitigation Standard (in Japanese), NASDA-STD-18, 28 March 1996.

[13]A. Kato, "NASDA space debris mitigation standard", 34th Session STSC UNCOPUOS, February 1997.

Sweden

[Original: English]

Sweden does not conduct any national research of its own on space debris, but supports the activities undertaken within the United Nations, ESA and other forums. Technical design studies are being carried out by industry (Saab Ericksson Space) on payload separation systems in order to mitigate the creation of new debris.

United Kingdom of Great Britain and Northern Ireland

[Original: English]

The United Kingdom plays an active role in dealing with the space debris problem. It has a comprehensive research programme looking at all aspects of debris and participates fully at national level through a United Kingdom Coordination Group, at European level through ESA, and at international level within the Inter-Agency Debris Coordination Group and the Committee on the Peaceful Uses of Outer Space. The programmes are coordinated by the British National Space Centre.

The British National Space Centre co-sponsored the Second European Conference on Space Debris held at the European Space Operations Centre (ESOC) during March 1997. The United Kingdom contributed 19 papers to the Conference addressing all debris issues ranging from measurements of the environment to modelling and recommended mitigation practices and technologies to perform these procedures. These papers are contained in the conference proceedings[1] produced by ESA.

The studies and resulting publications derived from United Kingdom organizations involved in debris research are given below.

A. University of Kent

The University of Kent through the Unit for Space Sciences provides a major contribution in all aspects of space debris research. In addition to participating in the Second European Conference on Space Debris, the group took part in the Hypervelocity Impact Symposium held in Germany in October 1996 and the Euromir Meeting in Paris in January 1997.

Building upon its experience of inferring encountered microparticle populations from examination of retrieved surface impact morphologies from the Long Duration Exposure Facility, the Unit has extended these skills to consider other retrieved objects such as the Hubble Space Telescope solar array. While significant effort has in the past focused upon damage caused by impactors incident upon the front face of the array, little attention has been addressed to the morphology of impacts on the rear of the array. The analysis compared 215 *in situ* space impacts with 41 impacts simulated in the laboratory. The morphology observed for the *in situ* impacts was reproduced by laboratory experiments permitting empirical ballistic limit relationships to be derived.

This analysis was extended to the EUropean REtrievable CArrier (EURECA) arrays[2] and measured over 1,350 impact images altogether. The impact sites were grouped by morphology and cumulative flux size distributions derived. Relationships were identified linking impactor size to ballistic limit and elliptical impacts were investigated.

An important element of *in situ* measurement of impacts is the comparison of observed impact distributions with those predicted by the environment models. The more advanced models represent directional and temporal variations in the populations and unlike retrieved surface analysis, dedicated detectors such as TiCCE (Timeband Capture Cell Experiment) can provide a method[3] of comparison for meteoroid stream models and assessment of asymmetries in the sporadic background of meteoroids, an important element in decoding the natural and man-made populations of particles.

In addition to identifying the velocity and direction of impact of particles encountered in space, an additional tool in discriminating between man-made and natural objects is determination of impactor density which is different for the two families of objects. Using impact relations for both thin and thick targets it has been demonstrated that impactor density can be derived and such an approach has been applied to both the Long Duration Exposure Facility and EURECA TiCCE data sets.[4] This analysis has also helped to identify new empirical relations linking impactor with surface damage observed on LDEF, MIR and EURECA.[5]

There is growing concern about the effect that the Leonid meteoroid stream could have on operational spacecraft during the expected storm event of November 1998/99. The Unit for Space Sciences has identified that the characteristic of the Leonid stream and its arrival in Earth orbit have the potential to generate or trigger discharge events. The Unit was closely involved in the investigation of the probable loss of the Olympus satellite in 1993 due to the impact of a Perseid meteoroid and concludes that several catastrophic events could occur during the expected peak of the Leonid stream at the end of the century.[6]

The value of having access to data sets from various spacecraft in different orbits at different times permits comparison to be made between flight conditions and for more comprehensive population characteristics and impact damage equations to be derived. When compared with impact simulations performed in the laboratory a clearer picture of the potential risk to satellite systems posed by microparticles can be developed.[7]

The Unit has a long heritage in developing and flying in-orbit sensors to detect the microparticle population. DEBIE (Debris In Orbit Evaluator) is one such sensor. The DEBIE instrument combines piezoelectric microphones with impact plasma sensing and foil penetration. It is a low-cost unit suitable for

flight on any spacecraft and thus could potentially offer the capability to map and monitor the evolving microparticle environment in those orbits used by operational spacecraft.[8] The versatility of the design and its low resource requirements make it suitable for both Earth orbiting missions and interplanetary space.[9]

There is still discussion on the origin and nature of an apparent excess flux of either space debris or micrometeoroids in Earth orbit. The Unit has carried out extensive examinations of potential capture processes whereby interplanetary fluxes may be captured into Earth orbit by gravity/atmosphere. The studies suggest that the Sun has a significant influence on these capture processes and Sun angle and solar cycle variations can be very important.[10]

Important comparisons between meteoroid populations and debris populations at altitudes of importance to operational spacecraft enable designers to apply appropriate protection strategies. At altitudes of 500 km and below, the Unit has shown that micrometeoroids are more prevalent than man-made debris.[11]

An issue that is beginning to receive greater attention is the population of secondary debris injected into orbit as a consequence of primary impactors striking spacecraft surfaces. This is important not only for representing new sources within environment models but also for ensuring that the populations inferred from retrieved surface analyses are not overestimated where secondary impact sites are confused with primary impact sites. The Unit has identified this secondary impactor phenomenon from analysis of the Hubble Space Telescope solar array.[12]

B. University of London

Complementary to the Unit for Space Sciences at the University of Kent, the University of London team at Queen Mary and Westfield College are developing models to represent the sources of microdebris encountered in space. This is a combination of ultraviolet degradation, atomic oxygen erosion, and hypervelocity impact. A series of empirical models are being developed to identify the amount of microdebris deposited into space as a function of orbital altitude and inclination, duration in orbit, spacecraft surface materials and the external space environment that was encountered.[13]

This work is supported by research into novel techniques for representing the collision dynamics and frequency for different populations of objects in orbit. One of the most promising approaches is that of Direct Simulation Monte Carlo which uses techniques derived from rarefied gas computations. The evolved environment predicted by this model approach and the flux observed on the Long Duration Exposure Facility for small impactors show good agreement.[14]

C. University of Southampton

The University of Southampton has concentrated on collision events and risk analysis over a shorter time frame. A set of modelling programmes called the Space Debris Simulation suite[15] considers the consequences of collision or explosion-induced break-ups and the short-term evolution of the resulting debris cloud. Using a generalized approach to the method of probabilistic continuum dynamics the software is able to follow the trajectories of the resulting fragments to determine the likelihood of collision with other objects, and if a collision were to occur, the level of damage that might be expected.

The model has been used to carry out proximity analyses for the break-up of a launch vehicle and an orbiting surveillance/remote sensing platform. Clear lessons can be learnt regarding the best choice of parking orbit and disposal orbit for launch vehicle upper stages in order to minimize the likelihood of fragments resulting from a break-up presenting a collision hazard to nearby assets.[16]

The method has further been applied to the novel case of a constellation of 800 satellites in low Earth orbit. The study considered the possibility of a collision-induced break-up and explosion. The objective was to identify the probability that the loss (break-up) of a satellite in one of the planes of the constellation would lead to the loss of a satellite in the same or adjoining planes, and possibly initiate a collisional cascade within the system. It was clear that the design of the constellation, number of satellites, planar distribution, orbital altitude and inclination, phasing and satellite size are the main parameters involved.[17]

D. Matra Marconi Space

Industry in the United Kingdom has begun to recognize the importance of dealing with debris at the design phase of a programme in order to minimize the costs of incorporating debris-related elements in platform configuration. A sound scientific programme aimed at understanding the fundamental physical processes of hypervelocity impact and how this relates to realistic spacecraft materials is considered of prime importance. Matra Marconi Space have exploited the experience of the Unit for Space Sciences at the University of Kent in order to understand how solar array materials respond to hypervelocity impact.[18]

With the support of a Royal Society Research Fellowship, Matra staff collaborated with NASA experts to investigate some of the fundamental impact processes. Comprehensive test programmes using light gas guns and relevant diagnostics were used to characterize in a rigorous manner the velocities distributions of secondary ejecta.[19] This research is also of interest to the planetary community in understanding the formation of bodies within the solar system.[20] Matra also collaborated with ONERA-CERT of France in order to carry out hypervelocity impacts simulations to distinguish between the morphology of impact sites created by elliptical impactors and impact sites created by oblique incidence spherical impactors.[21]

E. Century Dynamics

Century Dynamics have a unique capability to investigate the processes of hypervelocity impacts through development of the AUTODYN-2D[TM] hydrocode. In conjunction with the Unit for Space Sciences at the University of Kent, a programme of tests was performed to compare the response of brittle materials to a range of hypervelocity impact conditions. This work is very important because it allows a comparison to be made to assess the accuracy of the hydrocode simulation results but also provides a tool with which the designer can begin to investigate the response of characteristic spacecraft materials to impact by debris and meteoroids.[22]

One of the problems of using hydrocodes for the simulation of hypervelocity impacts is the computer-intensive nature of the solution. A balance between efficiency and accuracy must be accomplished in order to ensure that computation is a realistic and feasible tool for spacecraft design. Century Dynamics have invested a large amount of time and expertise seeking the most appropriate methodologies and solutions customized to particular applications.[23] This analysis can also include consideration of the use of particular customized processors.[24] In collaboration with the Defence Evaluation and Research Agency, Century Dynamics are developing the Smooth Particle Hydrodynamics approach to solve impact cases where a gridless technique is more appropriate.[25]

F. Defence Evaluation and Research Agency

The Defence Evaluation and Research Agency is responsible for the technical coordination of the United Kingdom's space debris research programme. In addition, the Agency has developed a number of software analysis tools.

The first is a suite of software called IDES (Integrated Debris Evolution Suite) which is able to provide an assessment of the future collision risk that will be encountered by spacecraft. The software is able to model

all launch and orbital activity including collisions, explosions, separations, and shedding. It is also able to propagate the orbits of the objects introduced into the space environment and consider the influence of gravitational perturbations, atmospheric drag and the influence of the Sun and Moon. A comprehensive testing programme has been carried out to ensure that the predictions agree well with observations. Using a combination of radar tracking data for larger objects and retrieved surface analysis for smaller objects, good correlation is found between predictions and observations.[26]

The confidence derived from good comparison with actual data has encouraged the users of IDES to use it in predictive mode. This has enabled the impact of future planned systems to be determined. The influence of low Earth orbit satellite communication systems on the growth of debris in orbit has been investigated in a series of studies.[27] It has been demonstrated that the coupling between the large number of new satellites and the background debris population will significantly increase the growth rate of objects in orbit. It is also clear that the constellation satellites themselves will be victims of collisions.[28]

Complementary to this environment modelling tool, a risk/design tool called PLATFORM is being developed to synthesize the predicted population data and configure a satellite to ensure its survivability from collisions with these objects. The approach represents the satellite as a combination of individual elements and positions these to provide maximum protection to the satellite components.[29] The PLATFORM model uses a novel element termed SHIELD[30] which uses genetic algorithms to determine the optimal configuration of a spacecraft based on the encountered environment and design constraints such as thermal and mass balancing. The combination of IDES and PLATFORM represents a powerful tool for design satellites to meet future technological challenges posed by space debris.

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REPLIES RECEIVED FROM INTERNATIONAL ORGANIZATIONS

International Law Association

[Original: English]

Full text of the International Law Association contribution will be available during the session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space.

International Telecommunications Satellite Organization

[Original: English]

A. Introduction

INTELSAT incorporates self-imposed policies and procedures to properly decommission "expended" satellites and to prevent the generation of space debris. The existing policies and procedures on the general satellite designs, launch operations, satellite operations, satellite anomalies, and satellite decommissioning are shown below.

B. General satellite designs

- INTELSAT satellite procurement documentation specifies designs which minimize outgassing and debris generation during transfer orbit deployments and in-orbit operations.

- INTELSAT utilizes satellite designs that are self-contained and generate no orbital debris.

- Satellites are equipped, when possible, with measurement devices to assist in determining end-of-propellant conditions.

1. Launch operations

- A dialogue is maintained with United States Space Command/NORAD; INTELSAT furnishes launch information and orbital parameters upon request.

2. Satellite operations

- Detailed satellite propellant budgets are maintained, including a record of all manoeuvres. Mathematical models are employed to calculate propellant usage and predict remaining reserves. These models are continually updated with flight data.

- A propellant uncertainty margin is used to "hold back" on-board propellant reserves and guarantee that satellites are not stranded in orbit.

- Multiple ground stations are used to track and command satellites in order to provide full redundancy during in-orbit operations or emergency conditions.

- Satellite telemetry is continually monitored and compared against preset limits. Alarms are utilized to alert ground teams of any anomalies.

- Battery capacity and power subsystem performance is continually monitored on all satellites. Emergency procedures are in place to "shed load" when low battery or power conditions are noted.

- Contingency plans and procedures are available for emergency response; on-call engineering staff are available for immediate 24-hour consultation.

- INTELSAT abides by standard protocols during orbital relocations and coordinates all activities with the other satellite owners/operators.

3. Satellite anomalies

- Contingency plans call for immediate orbit raising and decommissioning of any satellite that is likely to be stranded in the geosynchronous orbital arc. The Director of Satellite Engineering Support and Processes has authority for this decision; no other approvals or authorizations are required.

4. Satellite decommissioning

- At decommissioning, all satellites are placed into a safe, passive mode. This includes depressurization and venting of propellant systems as part of orbit raising, discharge of batteries, and turning off of all RF units to preclude interference with any other satellite owner/operators.

- For older satellites, sufficient propellant is held back for decommission orbit raising to a minimum altitude of 150 km above geosynchronous. This manoeuvre is normally done in multiple parts over several days to guarantee a good parking orbit. For newer satellites, starting with INTELSAT VI, a minimum decommissioning altitude of 300 km has been adopted. Because of conservative propellant budgeting INTELSAT normally exceeds the targeted decommissioning altitude.

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USES OF OUTER SPACE

STEPS TAKEN BY SPACE AGENCIES FOR REDUCING THE GROWTH OR DAMAGE POTENTIAL OF SPACE DEBRIS

Report by the Secretariat

CONTENTS

		Paragraphs	*Page*
INTRODUCTION		1-3	2
I.	AVOIDANCE OF MISSION-RELATED OBJECTS	4-11	2
II.	IMPROVED STRUCTURAL INTEGRITY OF SPACE OBJECTS	12-21	3
III.	DE-ORBITING AND REORBITING OF SPACE OBJECTS	22-39	5
	A. Low Earth and highly eccentric orbits	22-31	5
	B. Geostationary orbit	32-39	6
IV.	PROTECTION BY SHIELDING	40-46	8
V.	COLLISION AVOIDANCE	47-49	9

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INTRODUCTION

1. At its thirty-fourth session, the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space noted with appreciation the report prepared by the Secretariat on various steps taken by space agencies for reducing the growth or damage potential of space debris (A/AC.105/663), and recommended that it should be updated annually (A/AC.105/672, para. 90).

2. This recommendation was endorsed by the Committee on the Peaceful Uses of Outer Space at its fortieth session.[1]

3. The present report, prepared by the Secretariat in response to the above-mentioned request, contains a summary of the information provided by Member States, as well as by national and international space organizations. The format of the report corresponds to the format of relevant parts of the technical report on space debris that is currently being prepared by the Scientific and Technical Subcommittee.

I. AVOIDANCE OF MISSION-RELATED OBJECTS

4. Launch vehicles and spacecraft can be designed so that they are litter-free, in other words, they dispose of separation devices, payload shrouds and other expendable hardware (other than upper-stage rocket bodies) at a low enough altitude and velocity that they do not become orbital. This is more difficult to do when two spacecraft share a common launch vehicle. In addition, stage-to-stage separation devices and spacecraft protective devices such as lens covers and other potential debris can be kept captive to the stage or spacecraft with lanyards or other provisions to minimize debris. This is being done in some cases using existing or new designs where feasible. These practices should be continued and expanded if possible.

5. When the mission requires delivery of a spacecraft which itself has a manoeuvre capability, two alternatives are possible. One is to leave the upper stage attached for delivery of the spacecraft to orbit to maximize its manoeuvre capability. The second is to separate the spacecraft at suborbital velocity so that the stage decays naturally and the spacecraft uses its on-board propulsion to establish its orbit. From a cost-penalty perspective, the first alternative results in a greater mass in orbit—a potential debris hazard— while the second alternative increases the complexity of the spacecraft. Assessing which alternative is more appropriate requires further study.

6. The National Space Development Agency of Japan (NASDA) requires that the release of mechanical devices at satellite separation and solar panel deployment be avoided except in some particular missions, such as the separation of spent apogee motors for the geostationary meteorological satellite.

7. The principal rule established by the *Centre National d'Etudes Spatiales* (CNES) (French National Centre for Space Studies) to counter the proliferation of space debris is as follows: at the end of the launching mission, whatever the targeted orbit, there should be no more than one piece of passive debris rendered per satellite placed in orbit. In order to conform to this rule, CNES has incorporated the following debris-reduction techniques in the technical specifications of Ariane launch vehicles:

(a) In the case of a single launch, the orbiter must be rendered passive, which means that residual propellants, including the performance reserve and the propellants used in the attitude-control system, must have been emptied and the tanks depressurized;

(b) In the case of a multiple launch, the adapter structure must also be inert;

(i) The use of solid propulsion in orbit is prohibited (they create clouds of aluminium particles);
(ii) The end-of-life of electrical batteries and cells must not be accompanied by a critical rise in pressure;
(iii) Payload separation systems and multiple launching structures must not generate any debris (sealed pyrotechnic separation and trapping of explosive bolts and of straps);
(iv) The pre-flight mission analysis must make it possible to guarantee, with a probability higher than 1.10^{-4}, that there will be no collision between objects in orbit.

8. With regard to the minimization of new space debris, Surrey Satellite Technology Limited of the United Kingdom of Great Britain and Northern Ireland is applying the following practices in the development of all mini-satellites and microsatellites:

(a) Securing to the structure, whether the launch vehicle or the satellite itself, all the components or parts that might lose their original fastenings during the launching process, including the remains of components subject to breakage;

(b) Use of materials suitable for space in that they do not suffer damage as a result of outgassing or of other environmental conditions that might result in the creation of debris, including the surface treatment of the materials concerned;

(c) Ensuring that all the structural fastenings and all parts of the satellite as a whole are capable of withstanding the mechanical conditions of the launch, placing in orbit and subsequent operation, and of maintaining the integrity of the structure.

9. In order to minimize the creation of space debris, the Canadian Radarsat programme established a system-level requirement that any solid debris resulting from the operation of a restraint/release mechanism be contained. That is, all contractors were required to design a system such that no debris would be released by the spacecraft during its deployment in orbit.

10. Recently, the modernization of operative, and the development of new, space and rocket technology led space-related enterprises in the Russian Federation to undertake a number of preventive measures for reducing the level of space debris. For example, a new DM upper stage of the Proton launcher is under development, incorporating provisions to eliminate the separation of the engine starting system (SOZ motor) from the stage during its powered ascent into orbit, so that no additional debris are created.

11. The task of litter-free operations could combine design and operational practices to achieve the goal of limiting further orbital debris created by any space operations. As a result of these efforts, the growth rate of orbital debris will decline, although the overall debris population will still increase.

II. IMPROVED STRUCTURAL INTEGRITY OF SPACE OBJECTS

12. The debris produced by upper stage fragmentations now accounts for more than 30 per cent of the catalogued Earth-orbiting object population. As many as 82 per cent of all upper-stage break-ups could have been prevented by executing proper passivation techniques. During the period 1990-1996, a total of 28 upper stages—an average of four per year—associated with 10 different vehicle types broke up in Earth orbit. Although some of these events originated with old upper stages already in orbit for a long time, the vast majority of the vehicles were launched in 1988 or later, after widespread attention had been given to the issue of upper-stage passivation.

13. Perhaps the first significant debris-reduction policy has been the requirement of the National Aeronautics and Space Administration (NASA) of the United States of America for the venting of unspent propellants and gases from Delta upper stages to prevent explosions caused by the mixing of fuel residues. In August 1981, the company providing the Delta second stage implemented a new procedure calling for a restart of the stage engine to burn the remaining propellants to depletion. No Delta second stage that has performed this depletion burn has experienced a subsequent break-up. In 1985, NASA notified NASDA of the Delta second stage problem because the Japanese N-II launch vehicle employed a second stage based upon this Delta stage. Consequently, NASDA also adopted a passivation policy and no N-II second stages have broken up in orbit.

14. In August 1995, the NASA Office of Safety and Mission Assurance issued NASA safety standard 170.14, "Guidelines and assessment procedures for limiting orbital debris". Guideline 4-2 of this document addresses the issue of spacecraft and upper-stage passivation. It specifically states the following: "All on-board sources of stored energy will be depleted when they are no longer required for mission operations or post-mission disposal. Depletion will occur as soon as such an operation does not pose an unacceptable risk to the payload."

15. On-board energy sources cited in the standard include chemical energy in the form of fuels and explosives associated with range safety systems, energy in the form of pressurized volumes (as in sealed batteries, thermal control, attitude control and propulsion systems) and kinetic energy (as with control moment gyroscopes). The NASDA Debris Mitigation Standard and the draft *Space Debris Mitigation Handbook* of the European Space Agency (ESA) also strongly recommend upper-stage passivation measures.

16. Propellant elimination actions should also be designed to relieve high-pressure gases employed in pressure-fed propulsion systems. This can normally be accomplished by keeping propellant lines and vents open for longer periods. Alternatively, pressurants can be removed with the use of special venting lines and pyrotechnical valves. For vehicles where fuel and oxidizer is to reside in a common propellant tank, separated only by a membrane or wall, venting procedures should be designed to prevent the development of excessive differential pressures. Finally, stage passivation measures should include the disarming of the range safety system (that is, detonation charges) and the isolation and discharge of the electrical power system.

17. The principal energy source of upper-stage break-ups clearly appears to be residual propellants, whether in the form of hypergolics, cryogenics, monopropellants or simple oxidizers. More importantly, the removal of these energy sources has been 100 per cent successful in preventing future fragmentations. Residual propellant elimination is normally accomplished by initiating depletion burns or simply venting propellant tanks. The first option can require full propulsion restart, as practised by the Delta, Delta 2, Pegasus, and Japanese N-II programmes, or idle-motor burns, as demonstrated by the H-I and H-II upper stages. The United States Centaur hydrazine altitude control system also burns residual propellants to depletion after payload separation. To gain greatest environmental benefit from these burns, they should be performed in a manner that will reduce the orbital lifetime of the vehicle. Using this technique, the Delta second stage (1996-024B) reduced a projected lifetime of several hundred years to only nine months.

18. The third stage of the Ariane 4 launch vehicle was modified following the explosion in orbit of that stage that occurred nine months after Ariane 4 was used to launch SPOT 1 in 1986 (V16). Two pyrotechnic valves were designed and added to the pressurization circuit of the tanks, forcing the latter to open into the void at the end of the mission. Introduced in October 1993, this design modification has so far permitted 30 flights to take place without any anomaly, thus demonstrating the total effectiveness of the measures taken.

19. The Ariane 5 orbiter will also be rendered passive at the end of its mission through the opening of two pyrotechnic valves fitted on the pressurization circuit, connected to zero-torque nozzles. The main tanks have to be neutralized within 10 minutes.

20. The Ariane high-pressure helium tanks are designed to be emptied within a few hours via a calibrated orifice. The attitude-control system operating on hydrazine is to be emptied until a residual pressure reading is attained which safeguards the system against explosion under the impact of a micrometeoroid or orbital debris. The separation systems are checked for cleanliness in the course of development in accordance with specifications from the satellite developers.

21. NASDA has implemented the draining of residual propellants (LOX, LH_2, N_2H_4) and residual helium gas of the second stage of the H-I and H-II launcher. In order to prevent the unintended destruction of the H-II second stages in space, the command destruct system is disabled immediately after injection into orbit and its pyrotechnics are thermally insulated to preclude spontaneous initiation. Other launchers, such as Proton, Zenit and Long March 4 vehicles, have also incorporated venting passivation measures.

III. DE-ORBITING AND REORBITING OF SPACE OBJECTS

A. Low Earth and highly eccentric orbits

22. One of the most important of the NASA guidelines is the planned disposal of spacecraft and upper stages at the end of their useful life. Following this guideline reduces the growth of mass in the most frequently used regions of space and reduces the potential for having on-orbit collisions become a significant source of debris. However, since planned disposal is a new concept in most cases, it is perceived as a significant added cost burden on new programmes. In general, the post-mission disposal options are as follows:

(a) Direct retrieval and de-orbit;

(b) Manoeuvre to an orbit for which atmospheric drag or gravitational perturbations will remove the object from orbit within 25 years;

(c) Manoeuvre to one of a set of disposal regions in which the objects will not interfere with future space operations.

23. Retrieval means the return to the Earth, without damage to the spacecraft or other space hardware, by a space vehicle capable of atmospheric entry, such as the United Space Shuttle or the Russian Federation Soyuz re-entry modules. Examples of retrieved space hardware are the European recoverable carrier Eureca, the Japanese Space Flyer Unit, the United States Long-Duration Exposure Facility, Palapa-A, Westar-B and a solar array from the Hubble Space Telescope. Because of the limited capacity of the Shuttle and the relatively high costs involved, this method of debris mitigation is used only rarely.

24. De-orbit is an efficient method for removing objects from space. This includes propulsive manoeuvres to force an immediate destructive entry into the atmosphere and also reduction of the orbital lifetime under a certain limit (for example, 25 years) by lowering the orbit using propulsive manoeuvres or other methods, such as increasing the area vulnerable to atmospheric drag. For some missions, the performance of the launch vehicle leaves a sufficient margin of propellant available for the stage to do a de-orbit burn. The stage usually needs to be modified to provide the guidance and control capabilities needed for a controlled de-orbit after fulfilling its primary mission (which is the delivery of the payload into orbit). However, this might have a negative effect on the cost of the mission.

25. A controlled de-orbiting over deserted regions of the Pacific Ocean is regularly performed by the Russian Space Agency after its cargo craft of the Progress type fulfil a mission to the Mir orbital station. This method was used even during servicing of previous orbital stations of the former Soviet Union, starting with Salyut 6

in 1978. All Salyut orbital stations have been de-orbited over the Pacific Ocean with the exception of Salyut 2 and Salyut 7, which malfunctioned. Controlled re-entry is also planned for the Mir station in 1999. NASDA has no experience with controlled re-entry of spacecraft from high altitude, but the Tropical Rainfall Measuring Mission is supposed to re-enter into the ocean from an altitude of 380 kilometres to provide that kind of data.

26. According to the NASA standard, another alternative to a controlled direct entry is a manoeuvre that lowers the perigee so that the inertial orbital lifetime is constrained to a period of 25 years. Such a manoeuvre quickly removes the object from the region of high hazard and therefore removes the mass and cross-section from orbit in a small fraction of the orbital lifetime without such a manoeuvre. This is significantly less costly than a targeted entry. It makes the eventual re-entry happen earlier, but raises questions regarding liability issues, because the geographic region of the entry into the atmosphere could not be accurately predicted.

27. To be in accord with the NASA standard, NASDA, in its standard STD 18, also adopted 25 years as an allowable lifetime until mission-terminated space systems will re-enter by natural force into the atmosphere. For most systems, this occurs if the orbit is lower than 750 kilometres. In the case of higher orbits and if the re-entry risk would be allowable, the most feasible measure to avoid collision risk with other operating space systems is to reduce the orbital lifetime by reducing the perigee height of the orbit. However, this manoeuvring may require a propulsion system that might complicate the design of the system.

28. An alternative to natural atmospheric re-entry and controlled disposal over the ocean is relocation to a disposal orbit. In low Earth orbit, this is not an advantageous strategy because it generally requires a two-burn manoeuvre that is more costly in terms of fuel than the single burn that is required for entry. During the 1980s and early 1990s, the former Soviet Union used near-circular orbits at altitudes of 900 to 1,000 kilometres to dispose of 31 nuclear power sources. The NASA guidelines recommend manoeuvring to the storage orbit with a perigee above 2,500 kilometres and an apogee below 35,288 kilometres (500 kilometres below geostationary altitude).

29. For missions using the elliptical geostationary transfer orbit (GTO), the pertinent considerations for disposal of the upper rocket stage are the launch date, launch azimuth, and the perigee of the transfer stage. For multi-burn systems, positive ocean disposal can be achieved with an apogee burn of a few metres per second if the stage has sufficient battery lifetime and contains an attitude reference and control system.

30. In addition, there are sets of launch times to GTO aligning the orbit of the transfer stage so that natural forces, such as the properties of the Sun, Moon and Earth, act to lower or raise the perigee of the stage. Consideration of the effect of these forces can minimize the cost of active control of liquid propellant stages and is a low-cost technique for the disposal of solid rocket motor stages. The only alternative strategy for the disposal of solid rocket motors is to orient the thrust vector of the rocket in a direction so that the perigee of the transfer orbit resulting from the burn is at a low enough altitude to cause the stage to eventually re-enter (sometimes referred to as an off-axis burn). This strategy results in a performance of about 15 per cent for the stage.

31. The measures adopted for the NASDA programmes seem to be relatively inexpensive and have proved to be very effective. For example, the orbital life of the Japanese ETS-VI H-II second stage (1994-056B) was reduced to about seven months as a result of de-orbiting.

B. Geostationary orbit

32. There is an ever-increasing number of satellites in geostationary orbit (GSO). Since atmospheric friction is no longer a factor at this altitude, objects abandoned in this orbit do not move out of the region, thus presenting a hazard to other satellites, both the hazard of collision with operational satellites and also that of

an accidental explosion which would result in the creation of an extremely large number of debris fragments. The use of disposal orbits is currently the only technically feasible strategy for clearing the GSO region. However, it requires planning and reserving the necessary propellant resources to effect the manoeuvre. Preliminary studies indicate that the orbit needs to be raised by about 300 kilometres to serve the intended purpose, not by the 40 to 70 kilometres that have been used by some operators. The performance cost for reorbiting is 3.64 metres per second for each 100 kilometres, or 1.69 kilograms of propellant for each 1,000 kilograms of spacecraft mass. To reboost for 300 kilometres is comparable to three months station-keeping.

33. Study Group 4 of the Radiocommunication Bureau of the International Telecommunication Union (ITU), in which many satellite operators participated, endorsed the recommendation that all geosynchronous orbit satellites be boosted no less than 300 kilometres above the geosynchronous orbit at the end of life, and that the spacecraft then be made inert by discharging any residual propellants and gases and by "safing" of the batteries.

34. The International Telecommunications Satellite Organization (INTELSAT) incorporates self-imposed policies and procedures to properly decommission expended satellites and to prevent the generation of space debris. The existing policies and procedures on satellite decommissioning are as follows:

(a) At decommissioning, all satellites are placed into a safe, passive mode. This includes depressurization and venting of propellant systems as part of orbit raising, discharge of batteries and turning-off of all RF units to preclude interference with any other satellite owners and operators;

(b) For older satellites, sufficient propellant is held back for a decommission orbit raising to a minimum altitude of 150 kilometres above GSO. This manoeuvre is normally done in multiple parts over several days to guarantee a good parking orbit. For newer satellites, starting with INTELSAT VI, a minimum decommissioning altitude of 300 kilometres has been adopted. Because of conservative propellant budgeting, INTELSAT normally exceeds the targeted decommissioning altitude.

35. France has decided to introduce a voluntary policy of reorbiting of geostationary satellites at end of life in order to free the useful orbit. The solution adopted is to place satellites that have completed their mission in an orbit situated 300 kilometres above GSO. This policy has already been applied a number of times by CNES, which is responsible for monitoring a number of national satellites in orbit. The Telecom 1A telecommunications satellite was removed into this orbit in September 1992, followed by the Telecom 1C satellite at the beginning of 1996 and subsequently the TDF 1 direct television broadcasting satellite.

36. The United States National Oceanic and Atmospheric Administration, NASA and several programmes of the Department of Defense regularly boost satellites that are no longer functional into orbits above GSO to prevent the creation of additional debris by inadvertent collisions with other drifting satellites and to free valuable orbital slots.

37. The technology of removal of Russian Federation spacecraft from GSO at the end of their active lifetime is based on the use of the remaining fuel (for satellites of the Statsionar-D, Ekran-M and Gorizont series) and the provision of the necessary amount of additional fuel to ensure an increase of the mean altitude of the orbit by 200 kilometres (for new types of spacecraft).

38. The following ESA geostationary satellites have been reorbited so far: OTS 2 (orbiting at 318 kilometres above GSO), GEOS 2 (260 kilometres), Meteosat 2 (334 kilometres), ECS 2 (335 kilometres) and Olympus 1 (because of a failure, this satellite has been left in an orbit 213 kilometres below GSO).

39. To evaluate the adequate distance for disposal of the GSO spacecraft, the effects of long-term orbital perturbations was studied in Japan. The resulting value of the minimal distance is almost the same as that recommended by both ITU and NASA Code-Q, namely about 300 kilometres.The current minimum requested by NASDA is 150 kilometres and the target is 500 kilometres. Actual reorbiting is often more than required to eliminate the influence of possible errors arising from the measuring system.

IV. PROTECTION BY SHIELDING

40. For small debris that cannot be tracked from the ground, the only alternative to collision avoidance is protection by shielding. The international space station (ISS) is shielded to defend against a 1-centimetre impactor. The Space Shuttle was not designed for the orbital debris environment, but has been modified to make it more robust for the ISS assembly and operations missions.

41. For current Shuttle operations, flight rule A2.1.3.-32 minimizes the time with the payload bay forward or nose forward and payload bay up or out of the orbital plane, since these are more vulnerable positions. The most protected orientation is with the payload bay toward Earth and the aft of the orbiter in the forward direction. There is a factor of 20 between the worst and best orientation. The orbiter has experienced a significant number of impacts, with on average one window being replaced in every flight.

42. To achieve the requested reliability of ISS (maximum 10 per cent probability of penetration over 10 years), different shield designs are used to protect various critical components. More effective shields are placed in forward-facing areas where most impacts are expected, and less capable shields are located in aft and nadir-facing areas that are expected to be hit less frequently. In addition to being capable of preventing penetration by nominal threats, shields for ISS must be lightweight, low in volume (to fit the space shuttle payload bay) and durable in the space environment. ISS is also designed to allow for future shield augmentation if the threat increases or if the life of the station is extended.

43. More than 100 different shields have been designed to protect various critical components of ISS, although all of the designs are modifications of three primary shielding configurations: the Whipple bumper, the multishock (or stuffed Whipple) shield and the mesh double-bumper shield. The Whipple bumper, the simplest shield configuration, consists of a single plate of material (typically aluminium), called the bumper, spaced some distance from the underlying module wall (often called a catcher). The role of the bumper is to break up, melt or vaporize a high-velocity object on impact. The smaller, slower remnants of the object then travel between the bumper and the catcher and spread the remaining energy of the impact over a larger area on the catcher. This configuration has been studied experimentally for over half a century. The Whipple bumper is most effective at high-impact velocities.

44. The stuffed Whipple bumper consists of an outer bumper, a catcher and one or more underlying layers of materials spaced between the bumper and the catcher to further disrupt and disperse the impactor. This arrangement results in an improved performance over the standard design and, with some bumper materials (like Nextel), reduced production of secondary ejecta. In current ISS designs, the outer bumper is made of aluminium and the shield is usually stuffed with six layers of Nextel and six layers of Kevlar. The module wall serves as the catcher. The mesh double-bumper is the newest NASA derivative of the Whipple bumper concept. Developed during the early 1990s, this shield has a metallic mesh disrupter in front of each of two bumpers. This design also provides significantly improved performance over the standard Whipple bumper.

45. For the foreseeable future, the non-Russian ISS crew will use the extravehicular activity mobility unit currently used by space shuttle astronauts. This space suit is protected by multiple layers of material and a single bladder that together provide a pressure vessel and a degree of protection from the thermal extremes of space and from meteoroids and debris. A secondary oxygen pack will provide at least 30 minutes of supplementary oxygen, should a hole up to 4 millimetres in diameter develop in the suit. There are multiple-failure recovery

modes from other impact-induced failures. Analysis shows that more than 75 per cent of the hazard will result from penetrations of soft parts of the suit (that is, arms, gloves, and legs). The ISS programme is considering augmenting the arms and legs with removable gauntlets and "chaps" to reduce this hazard.

46. The Canadian Radarsat spacecraft, successfully launched on 4 November 1995, is protected from the existing space debris environment. Protective measures were undertaken in order to ensure, to the best extent possible, that the Radarsat spacecraft does not prematurely become space debris as a result of a space debris impact. The measures involved defining the space debris environment to be encountered by Radarsat using the NASA ENVIRONET database. Individual spacecraft components were then examined to determine their vulnerability to the predicted environment. The vulnerability assessment included using hypervelocity impact equations as well as actually subjecting spacecraft hardware to hypervelocity impact tests at the NASA Johnson Space Center. Where required, shielding was added to the spacecraft in order to bring the survivability of the spacecraft to an acceptable level. The shielding included adding Nextel (a 3-M ceramic fibre cloth) to thermal blankets, adding bumpers in front of exposed hydrazine lines and wire bundles and thickening some component boxes in order to protect their enclosed circuits.

V. COLLISION AVOIDANCE

47. The United States launch planning is also affected by projections of the Collision Avoidance on Launch Program which warns of potential collisions or near misses for manned or man-capable vehicles before they are launched. The procedure is executed by the United States Eastern Test Range and provides clearance of 200 kilometres along the orbit and 50 kilometres both radial and out of orbital plane for manned vehicles. Should this procedure indicate a possibility of conjunction, the launch is held to the next even minute.

48. For United States manned Shuttle missions, mission rule A4.1.3.-6 addresses on-orbit debris avoidance. The Space Control Center (SCC) of the United States Space Command runs a computer program evaluating the next 36 hours of the Shuttle flight to determine possible trackable conjunctions of space objects within a radius of 100 kilometres around the orbiter. If an identified object is predicted to pass within the warning box near the orbiter (25 kilometres along the orbit and 5 kilometres both radial and out of orbital plane), the Space Surveillance Network is requested to make additional observations and use them to compute a more accurate orbit of that object. When improved prediction confirms the conjunction within the avoidance manoeuvre box (5 kilometres along the orbit and 2 kilometres both radial and out of orbital plane), an assessment is made as to whether to execute the manoeuvre or not. If a manoeuvre is executed, it is nominally 0.3 metres per second at an expenditure of 12 to 20 kilograms of propellant. Since 1986, on the eight occasions when the avoidance box was entered, three avoidance manoeuvres were executed. On the other occasions, mission objectives precluded the opportunity to manoeuvre, or the tracking trend indicated that it was not necessary.

49. When NASA crew are stationed on board the Mir orbital station for missions of long duration, a procedure developed to provide advisories to the Russian Mission Control Centre (CUP) at Korolov, near Moscow, is used, just as in the case of the Shuttle. When SCC identifies an advisory condition, a laptop is used with any available telephone line to establish an Internet and fax connection to CUP and a warning message is sent. Since the procedure became operational, five advisories have been provided. Since the Mir station cannot manoeuvre, the only crew action feasible is to take refuge. On 15 September 1997, the Mir crew took up position in the Soyuz re-entry module at the time of the forecast conjunction with the United States satellite MSTI 2 (1994-028A). The development of this procedure has given some insight into the procedures that will be needed for the future ISS. It is estimated that 16 conjunctions a year will occur for ISS if the same criteria are used for it as for the Shuttle.

Notes

[1] *Official Records of the General Assembly, Fifty-second Session, Supplement No. 20* (A/52/20), para. 85.